The Visual Perception of Distance
in
Young Children and Adults

Ruth Updegraff

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FOREWORD

Dr. Updegraff presents in this monograph new data on one of the traditional problems of psychology. Both technique and findings are unique in that they relate to age ranges of children which have not been generally held susceptible to a standard laboratory approach.

These preschool children proved surprisingly able to grasp the demands of the experimental situation, and it is felt that the conclusions reached here on acuity of visual perception of distance are as valid with respect to the children as to the adults. Children proved more variable than adults in the perception of distance, but the difference in accuracy was not great. In general the adults were favored on account of the possibility of their applying to the situation external experiences and associations. The study describes interesting possibilities in the way of extending the major inquiry to long distances and to children below the age of four.

It is likely that pure and genetic psychologists will find much encouragement in the success with which Dr. Updegraff has carried on this research in child psychology, with every indication of appropriate rigor and no suggestion of harm or even disinterest on the part of the children involved.

George D. Stoddard

Office of the Director
Iowa Child Welfare Research Station
State University of Iowa
July 1, 1930

Bureau Ednl. Psy. Research
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CHAPTER I

STATEMENT OF THE PROBLEM

The multiplicity of modern life with the resultant complexity of stimuli and their movements has given the problem of visual distance perception a significance heretofore not approximated. A study of the acuity of visual perception of distance in early childhood has, therefore, in addition to a direct meaning accruing from the child's continuous need for spatial reorientation, a derived importance from the developmental standpoint.

The aims of this study were to investigate the acuity in visual perception of distance of four-year-old children, to study the influence on this acuity of the two factors, size of the retinal image and linear perspective, and to compare the resulting data with other data similarly obtained through experimentation with adults. As the experiment evolved a secondary study developed, that of the young child as a reliable observer in a psychological experiment of the analytical type. After a preliminary investigation designed to study the young child's equipment in vocabulary referring to relative distance, apparatus was constructed to determine acuity at a distance of five meters. The observations were made in a dark room on the nearer of two light-stimuli and in later experiments a comparison was made of the thresholds thus obtained with those obtained after the variation of the size of the retinal image and of the linear perspective.

Two other techniques for studying distance perception in children were developed and tried out in a preliminary way. The first investigated acuity of distance vision at a range of 195 meters; the second investigated acuity at one meter.

The children observing in this study were in daily attendance at the preschool laboratories of the Iowa Child Welfare Research Station. They were well acquainted with the experimenter and oriented to the laboratory situation.

In the main experiment there were sixteen observers, ten children and six adults. Eighty-nine children ranging in age from two years seven months to six years five months and fifteen other adults observed in the supplementary experiments.

CHAPTER II

RELATED STUDIES IN THE VISUAL PERCEPTION OF DISTANCE

There are no experimental data on the subject of the visual perception of distance of young children six years of age and below.

Kuroda (20), in 1926, reported the reactions of his eighteen-months-old daughter in a few situations involving distance perception. The child was made to go around a table in order to obtain a piece of candy which she could plainly see. A record was kept of the number of times she chose the shorter route, and variations were made to offset orientation. The results were equivocal as was to be expected from the fact that a successful reaction necessitated not only a simple perception of distance but also a knowledge based upon experiential factors and an elementary form of reasoning. Anderson and Weymouth (1) determined the threshold for distance perception of four children, aged six, seven, eight, and eleven years, at two meters and concluded from results not given in detail that these children were capable of binocular perception of depth and able to compete with adults. Reber (28), in 1916 made a statement not supported by data that many children do not develop binocular perception by the age of twelve.

In the absence of experimental data other sources less direct in nature point to the fact that at the beginning of the child's third year his visual perception of distance is sufficiently developed for him to be spatially oriented. Two lines of evidence lend support to this assumption: (1) the child's visual acuity as indicated by physiological development of the eye in infancy (9), (30) and by observational reports of the vision of individual children; (2) observational studies which report distance perception on the part of individual children.

Various writers have reported observational notes on reactions of the child to light and to objects in the visual field.

Observers agree that at birth there is a sensitivity to light. Peterson and Rainey (25) assert this on the basis of examination of 1060 babies at the New York Lying-in-Hospital; visual reactions were tested by electric light, candle, match, sunlight, sunbeam, and window light. Blanton (2) found that a large percentage of the babies which she examined (number not stated) fixated the electric ceiling light at birth.

The movements of the eyelids are not at first coördinated with those of the eyeballs, nor with each other; winking is not innate. Preyer (26) placed the first signs of winking as a reaction to a sudden movement toward the eye at three months, Major (21) at forty-nine days, and Tanner (36) at forty-three to sixty days.

At first, the movements of the eye are not coördinated nor controlled. Preyer (26) reported that at the end of the third week there was still not always correct fixation; when his child was three months old uncoördinated movements of the eyes were no longer seen. Major (21) set the date of development at about the fifth week or a little later, seeming to depend on Preyer for his authority, however. Shinn (31) put the date at the twenty-fifth day. Preyer (26) analyzed the stages: staring, turning the head from one motionless, bright surface in the field of vision to another, following a bright object in motion, directing the eyes toward an object. Blanton's observations (22) would not verify these stages; she found that many infants a few moments after birth could follow with their eyes a slowly moving hand; a dim light which was slowly moved at a distance of .5 meters from the child was followed by children aged eight and thirty-six hours and three, four, five, six, fourteen, fifteen, twenty-one, and thirty days. According to these findings development of the eye proceeds at varying rates with individuals. Jones (18) found coördination developing at from thirty-three to 130 days.

The power of accommodation is somewhat later in development. Preyer believed that binocular fixation must be inexact long after the first voluntary act of accommodation, for irregular eye movements were thereafter still frequent. According to Preyer, the powers of accommodation are already in action at the ninth week. Shinn (31) placed the age at eight weeks. Moore's (23) date is somewhat earlier, the thirty-first day.

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Suggestions as to the development of distance perception have come for the most part from the attempts of the child to get possession of objects. There is, unfortunately, always the possibility that faulty motor control may give the opportunity for incorrect interpretation; in seeming to grasp, a child may be merely indicating a wish for possession. It is not possible here to go into an account of the development of the grasp; a rather full account of a single case may be found in Shinn (32). Preyer (26) noted in the seventeenth week that his child often grasped at objects twice the length of his arm away from him; in the eighteenth week reaching too short for the distance was frequent; in the sixty-eighth week the child did not reach far enough to seize objects.

According to Major (21) there is agreement among observers that the child has no perception of distance before the fifth month; with his own child he carried on a series of experiments in which he held before the child some of his toys; part of the time they were at too great a distance to be reached and part of the time they were within reaching distance. On the 134th day he invariably tried to get his hand on the toy. The same results ensued on the 141st day. On the 146th day the child refused to reach for toys held at a distance of two feet from him but did reach for them if they were held almost within reaching distance. The 169th day found him unwilling to reach for toys if the distance from his chest was eighteen inches; his judgment of the point where he could get his hands upon them was surprisingly good. Tiedmann's child (24) on his fifty-seventh day was thought by his father to have gained a knowledge of distance in case of nearby objects; on the seventy-ninth day it was noted that he made no attempt to reach objects not immediately convenient to his hand. At the age of three months he was reaching for distant things with his mouth. It was noted when the child was twelve and one-half months old that he attempted to leap from every elevation. When he was four months old he did not like to be lifted very high; this points to the fact that there was some sort of perception of distance, yet at twelve months of age the child was recorded willing to step off from any height. Russell (29) makes the same comment concerning his son at the age of twenty months.

Shinn (32) noted on the 239th day that the eyes judged the distance and this judgment determined whether the method of locomotion should be walking or creeping. On her niece's first birthday she was attracted by the moon and a few days later asked to have it. In her seventy-second to seventy-fifth weeks she repeatedly mistook one of two boys for another at a distance of twenty yards. Miss Shinn explained the mistake not by a defect in distance vision but by a failure to observe and fix in mind those general aspects by which one recognizes persons at a distance. On her 645th day the child mistook a white cow on a distant hillside for a goat. Late in her third year she thought that horses on a far away hillside were pigs.

Moore (23) stated that on the fifty-seventh day her child had the concept of distance. He reached for what was in range of his arm and did not try for what was beyond. In the sixteenth week he did reach for objects beyond the arm range, at the same time leaning towards them or moving the body in their direction. In the forty-first week the hand and arm movements corresponded to small distances perceived by the eye. By the forty-sixth week he was familiar with lengths to be traversed and found no difficulty in accommodating himself. When, in his sixty-first week he moved to a new home it took him three days to adjust to the distances. However, when another move was made in the sixty-second week the same difficulties were not found. Mrs. Moore mentioned that estimation of horizontal distances was better than that of vertical distances.

The foregoing observations, subjective in nature as they may be, indicate that the child's powers of accommodation and convergence are fairly well developed by the sixth month of his life and that his visual acuity enables him to see distant objects. By the end of the second year children are thought to have a practical perception of all objects except those far away; objects at a great distance may be inaccurately perceived as to size.

Binocular thresholds determined under varying conditions with adults as observers may be summarized for purposes of later comparison. The results of Wundt (38), Hering (12), Helmholtz (10), and Greaff (9) have no specific bearing on this study in that they have been superseded by subsequent finer determinations made by more refined methods. Heine (11) found that at five meters the threshold was reached at 12″ and 13″ angular displacements, although at nearer distances the perceptible angle decreased in degrees of arc. Stratton (35), in 1900 found that his subjects sensed differences of 7″ in a displaced line. In 1902 Bourdon's observers perceived differences in distance between threads in which there was an angular disparity of 5″. Howard (14), in 1919 stated, on the basis of experimentation with aviators, who have exceptionally high visual acuity, that the binocular parallactic angle discriminable by normal individuals at a distance of six meters is 8″. The same authority (15), experimenting later at a distance of 100 meters found that ten adults were able, on the average, to discriminate on the basis of 5.19″ angular disparity of two twelve centimeter semaphores. Anderson and Weymouth (1) who used three threads at a distance of two meters found that angular displacements of 1.94″ were perceptible under optimum conditions; they also expressed their results in size of retinal image, the range being .216 to .074 microns.

Ptolemy (10) is reported to have pointed out in 150 A.D. that the human mind forms an opinion of the size of an object after having made a preliminary estimate of its distance. Since that time both lay and scientific opinion have agreed that visual perception of distance depends to some degree upon the comparison of the size of the retinal image of the object concerned with the remembered size of the image when the object is near enough to be touched. Little detailed experimental work has been done on the subject previous to the last fifteen years. The experiments of Hillebrand (13) and Blumenfeld (3), whose investigations most closely relate to this study, do not bear on our problem in that the conditions of the experiments emphasized angular differences and the *Aufgabe* concerned size rather than distance. Anderson and Weymouth (1) believed from their experimentation that the size of the retinal image influenced distance acuity directly rather than empirically; since the visual angle which corresponded to the macula produced the lowest thresholds it seemed that maximum acuity was met at this point. Von Kries (10) states, "On the whole it is fair to assume that there is a coöperation between the empirical factors and binocular vision. . . . and that at least under certain circumstances the quantitative relations of binocular vision may be modified by those of the empirical factors. But to what extent this occurs, can hardly be estimated at present with any certainty; and, in addition, it is probable that individual differences are of such importance here."

The experiments of Hillebrand (13), of Blumenfeld (3), and of Gellhorn (8), bear upon the problem of linear perspective, bringing out the fact that apparent perspective and mathematically calculated perspective do not correspond. None of these investigations has particular relation to this study.

CHAPTER III

EXPERIMENTAL PROCEDURES FOR STUDYING ACUITY AND CERTAIN RELATED FACTORS IN VISUAL PERCEPTION OF DISTANCE

Inasmuch as this study attempted several approaches to the problem of visual perception of distance in young children, four experiments were evolved in the course of its development. The first was preliminary in nature to the second, which was the main experiment; the third and fourth were secondary experiments designed to develop apparatus and techniques for the study of different aspects of the whole problem of visual distance perception in young children. Despite the differences in the procedures of these experiments, there are several points of similarity:

1. Judgments required were always concerning relative, rather than absolute distance; that is, the observer was always enabled to judge the distance of one object in terms of another.
2. Judgments were always associated with some movement on the part of the observer.
3. If distance vocabulary was used in the course of the experiment, judgments were made in terms of the nearer object, with the exception of one section of Experiment 1.
4. There was a definite attempt to make the experiment an agreeable one for the observer.

In order to make comparative study possible, both children and adults were used as observers in two of the experiments, the main experiment and secondary experiment B.

PRELIMINARY EXPERIMENT: A STUDY OF CHILDREN'S CONCEPTS OF RELATIVE DISTANCE

This experiment, preliminary in nature, was designed to discover whether the young child's concept of distance is sufficiently developed for him to understand the two words, "nearer" and "farther" when they are applied in an unfamiliar situation. It seemed that ability to recognize the meaning of words referring to relative distance is indicative of a concept of relative distance. Not only was it desirable to know whether a child had developed an understanding of relative distance but knowledge of his ability to use words referring to it was also necessary before the development of experimental techniques. Accordingly, this method attempted a preliminary investigation of the vocabulary of two-, three-, four-, five-, and six-year-old children as it bears on the comparative aspect of distance, that is (1) "nearer," (2) "farther," (3) "closer."

APPARATUS

Two black linen threads were stretched 10 cm. apart on the length of a table 100 cm. long; knots were tied at 10, 15, 45, 60, 65, 85, and 90 cm. in each thread. Across the width of the table at one end a wooden screen 70 cm. by 50 cm. and 6 mm. thick, was fitted tightly into a groove cut about 3 cm. into a block of wood 51 cm. by 5 cm. by 5 cm., clamped to the end of the table. Two 5 cm. wooden cubes completed the apparatus.

For a supplementary experiment a block of wood 18 cm. high and 5 cm. by 5 cm. was used with an iron rod 2 cm. in diamemter and 5 cm. long.

METHOD

The child was seated at the end of the table squarely in front of the space bordered by the two threads. The chair was so placed upon blocks that the eyes of the child were 31 cm. above the level of the table top. The screen was between him and most of the table, so that he could not see the adjustments made by the experimenter for the various positions in the series. The cubes were placed along the outer edges of the threads and the distance was measured between the side of the cube nearest the child and the edge of the table. The seven paired distances given below represent the series as presented subsequent to several eliminations; the first series of ten pairs had been found too fatiguing.

Order of Presentation	Left	Right
1	45 cm.	60 cm.
2	65 cm.	60 cm.
3	10 cm.	
	20 cm.	
4	85 cm.	90 cm.
5	10 cm.	20 cm.
6	60 cm.	60 cm.
7	20 cm.	20 cm.

The last two pairs in the series were inserted to determine to what degree the child was open to suggestion.

The experimenter adjusted the cubes to the first position and pulled the screen away to the right of the child; she said, "Do you see these blocks? I want you to point to the one that is farther away." After she recorded the child's response the experimenter slid the screen in front of the child and adjusted the cubes for the next position.

Immediately after this series the same pairs were presented to the child. This time he was asked to point to the nearer block. If he failed to understand "nearer" he was asked to point to the "closer" block.

Correct response at all positions was assumed to mean that the child understood the words. Any doubt necessitated a retest.

On a later day the child was guided to a spot on the floor directly below the ceiling light. The experimenter said, "Do you see the ceiling? Do you see the chandelier? Which is farther away from you, the ceiling or the chandelier? . . . . Which is nearer to you, the ceiling or the chandelier?" Immediately afterwards the judgments of distance involving the block of wood and iron rod were made. The rod was on top of the block which stood on end on the floor. The experimenter led the child over to them and asked, "Which is farther away, the floor or the rod?" . . . . "Which is nearer, the rod or the floor?"

MAIN EXPERIMENT

The following experiment, the most extensive in this study, had as its object the determination in four-year-old children and in adults of the acuity of visual perception of distance at five meters, and the study, in relation to this acuity, of the influence of linear perspective and size of the retinal image. Since individual differences of significant nature were to be expected, it was thought best to work on an intensive, rather than an extensive basis. Accordingly, the observers were ten children ranging in age from four years, three months to four years, eleven months and whose intelligence quotients on the Stanford revision of the Binet scale ranged from 100 to 137, and six adults who were graduate students or members of the staff at the Iowa Child Welfare Research Station. Optical examinations, by the skiascopic method, were given to all children by a practicing ophthalmologist. Most of the adults wore corrective glasses.

APPARATUS

A dark room ten meters long was used for the apparatus which was especially constructed for the experiment. The main part of the apparatus consisted of two adjacent tracks, parallel to each other, horizontal, and eight meters long, upon each of which ran a box 35.5 by 35.5 by 35.5 cm.; the boxes moved on rope belts and were controlled by two cranks, one for each box, which were located at the far end of the tracks from the observer (Figure 1). The

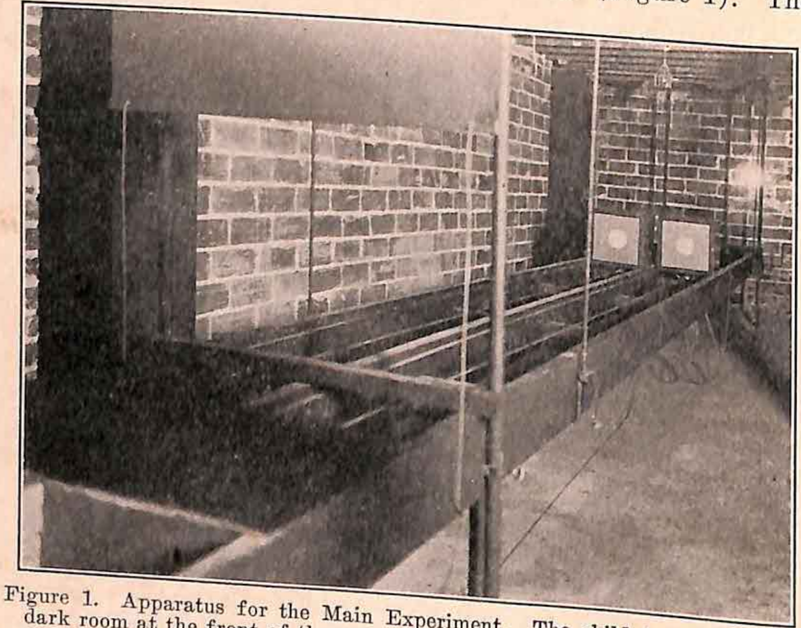

Figure 1. Apparatus for the Main Experiment. The child is seated in the dark room at the front of the apparatus (to the extreme left of the photograph), he judges which of the two circles of light in five paired positions is nearer him.

tracks, attached to four iron rods which were fastened to both floor and ceiling, were adjustable to any height, moving up or down on the rods by means of 400 pound weights, controlled by pulleys. Position at a given height was maintained by screws fitting into the rods.

The boxes, made of solid oak in order to prevent warping, had tops hinged at the back. The front side of each box was of frosted glass lined by several thicknesses of tracing cloth (Figure 2); within each were two fifteen watt bulbs, one white and one red, placed in a straight line in the center of the box parallel to the sagittal plane. The white bulb was so raised that its center corresponded to the center of the front side of the box; the red light was 15.5 cm. back of the white. The latter was small and spherical, the former more elongated. The stimulus circle, of evenly diffused white light, had an illumination of .5 foot-candle per square foot. A rheostat kept the voltage constant at 100.

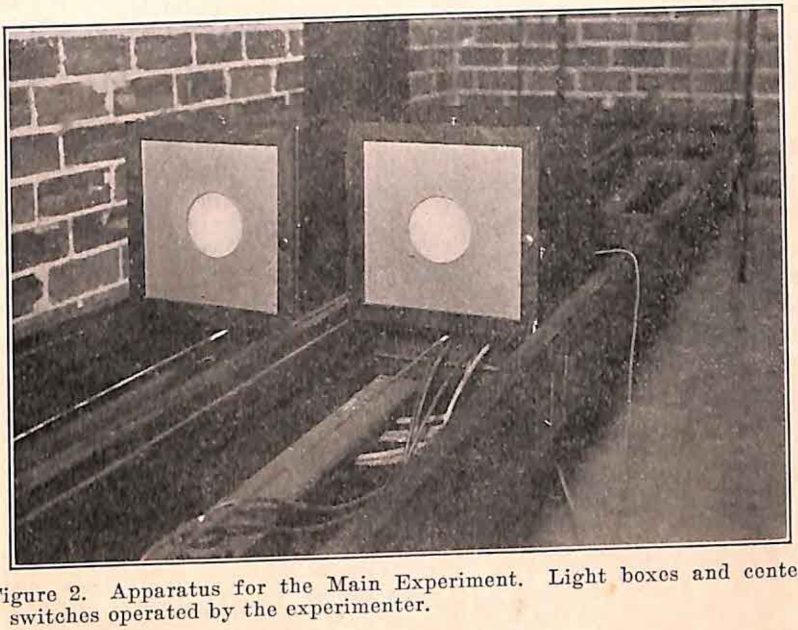

Figure 2. Apparatus for the Main Experiment. Light boxes and center switches operated by the experimenter.

A frame was so hinged to the box in front of the glass that a heavy cardboard screen could easily be inserted and withdrawn; hooks that were placed at the side of each frame so that the experimenter could easily reach them, held the screens firmly in place, after the frame was adjusted. Thus, if a screen having in it a stenciled pattern was inserted behind the frame in front of the frosted glass of the box, the only visual stimulus was that part of the screen through which the light could shine. The screens used were all of one-eighth inch cardboard, cut the size of the front glass. The standard screen had a hole cut in its exact center, twelve centimeters in diameter; this stimulus, then, had an area of 113.1 + sq. cm. and resulted in a visual angle of 1°21′ 39.3″ forming an image on the retina of .10178784 sq. mm. or 101.78784 microns.

At the front end of the tracks was attached a table to which, in turn, was fastened an adjustable headrest (Figure 3). Set into the table, directly in front of each track, was an electric switch of the push-button type and a buzzer-button. Each pair (Figure 4) of switch and button could be operated simultaneously by a lever. Each of the buzzer-buttons was connected to a buzzer of its own; the buzzers, different in pitch, were activated by two dry cells. On the side of the track nearest to the experimenter were three switches: one turned on the white light in both boxes; one threw open the circuit between the observer's switch in front of the left box and the red light in the left box; and one threw open the circuit

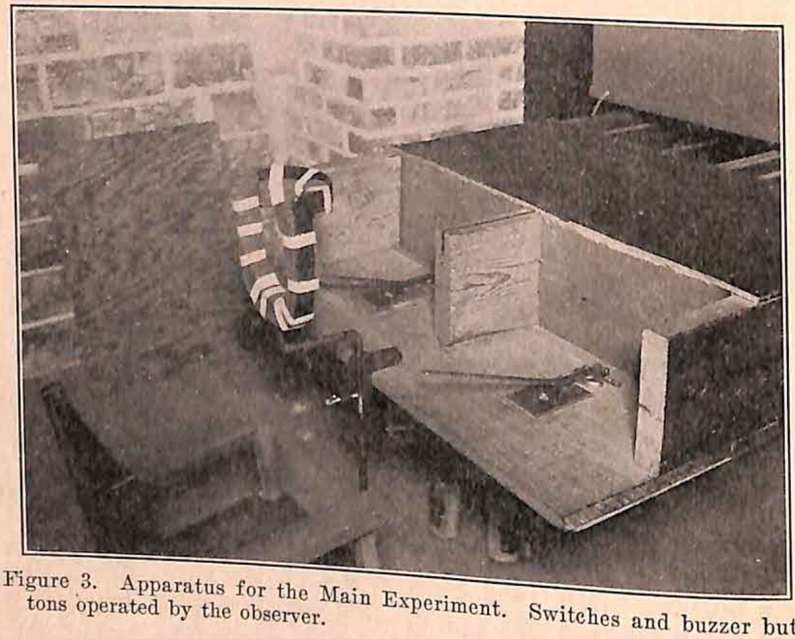

Figure 3. Apparatus for the Main Experiment. Switches and buzzer buttons operated by the observer.

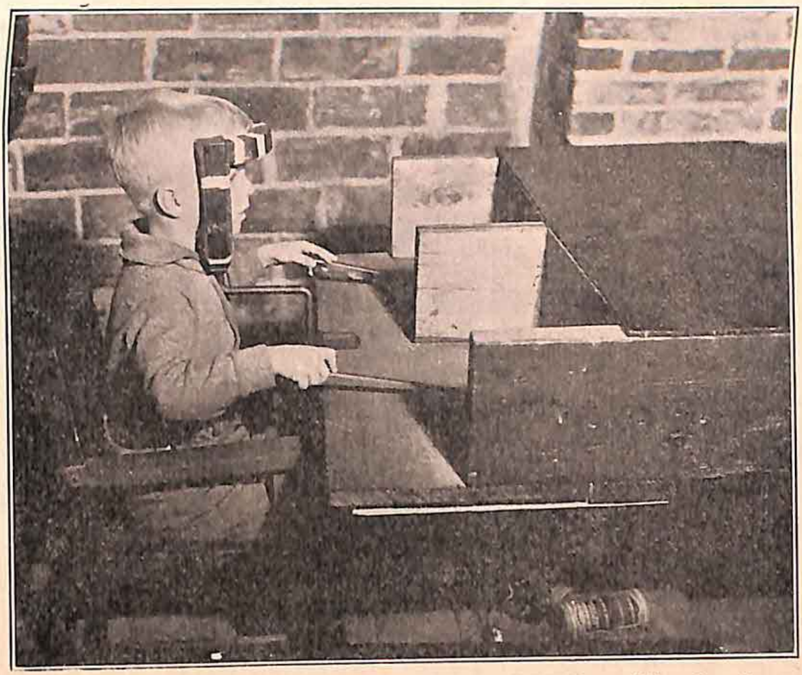

Figure 4. Apparatus for the Main Experiment. M382 in position for observation.

between the observer's switch in front of the right box and the red light in the right box (Figure 5). When the observer pressed the right switch, therefore, if the circuit were open to the red light in the right box, the white stimulus light would turn to red; if the circuit were not open there would be no change in the light. In either case the buzzer operated by the right lever would be heard.

A steel measuring tape was stretched down the center of the tracks, from end to end; the distance between the beginning of the tape and the observer's eye had, therefore, to be kept constant. The constant distance was twenty-five centimeters.

A black roller shade about one meter from the child, operated by means of an extension cord by the experimenter at the back of the apparatus where she stood, kept the observer from seeing the objects except during the judgment. The entire apparatus was painted flat black. Any reflection upon the tracks could not be seen by the observer because of a small black board placed upon the tracks directly under the roller shade.

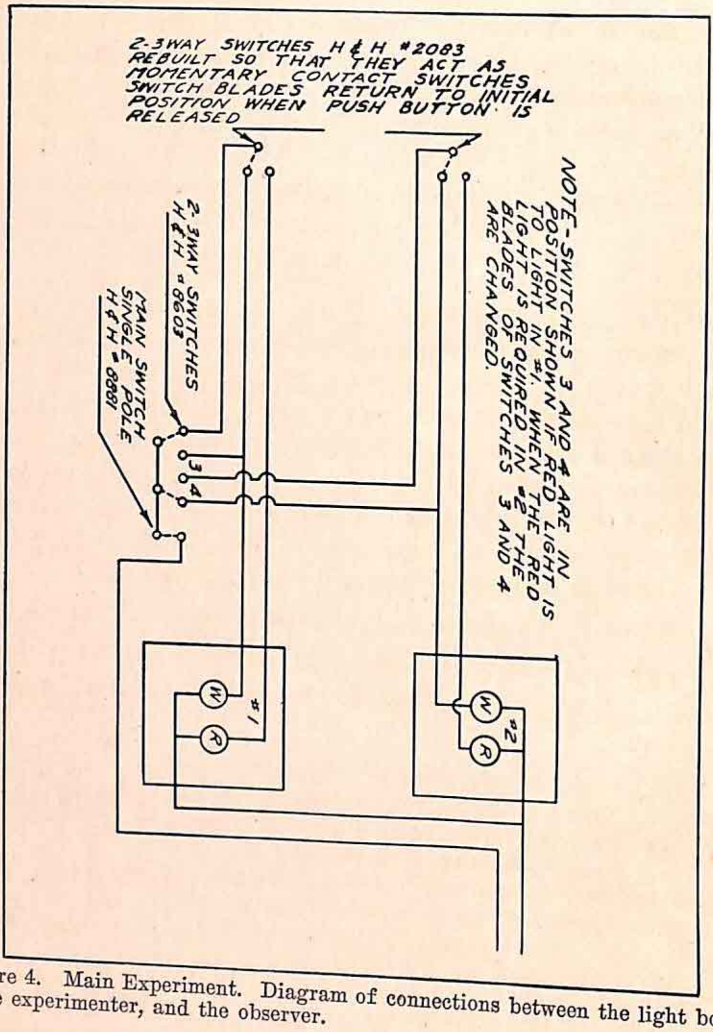
2-3 WAY SWITCHES H & H #2083
REBUILT SO THAT THEY ACT AS
MOMENTARY CONTACT SWITCHES
SWITCH BLADES RETURN TO INITIAL
POSITION WHEN PUSH BUTTON IS
RELEASED
NOTE-SWITCHES 3 AND 4 ARE IN POSITION SHOWN IF RED LIGHT IS TO LIGHT IN #1. WHEN THE RED LIGHT IS REQUIRED IN #2 THE BLADES OF SWITCHES 3 AND 4 ARE CHANGED.
2-3 WAY SWITCHES H & H #8603
MAIN SWITCH SINGLE POLE H & H #8881
3
4
W
R
#1
W
R
#2

Figure 4. Main Experiment. Diagram of connections between the light boxes, the experimenter, and the observer.

METHOD

It was the aim of this procedure to exclude accommodation as a factor in distance discrimination and yet to carry on the experiment at as near a distance as possible beyond this limit; the latter provision was made in order that the child would neither feel detached from the experiment nor far away from the experimenter. Starling (33) states that accommodation is non-effective beyond five meters; Titchener (37) places the outer range for distance discrimination at two meters. Although Howell (16) places the far point at six meters, Howard (15) states from his experimentation that accommodation is not a factor in binocular vision. Anderson and Weymouth (1) considered accommodation to have been eliminated by a two meter distance.[1]

It is not possible to state the outer limits of convergence; Titchner (37) placed them at 15-20 meters, but information on this point is meager.

Adjustments of the Apparatus

An illuminated circular area 12 cm. in diameter at a distance of 505 cm. from the eye was arbitrarily chosen as a standard; it was thought to be far enough away to give good angular change and too far to allow the muscles of accommodation to have an effect. The stimuli were presented in five selected pairs, the distances having been determined in preliminary experiments with each individual so that they extended up to and beyond the threshold zone; they were planned so that the standard distance was compared with the standard minus x distance with standard minus $\frac{x}{2}$ distance, with equal, with standard plus $\frac{x}{2}$ distance, and with standard plus x distance away from the observer. There were nine comparative series:

Binocular Series

Series 1	Two circles, each 12 cm. in diameter in center of screen.
Series 2a	Two circles in center of screen, one circle 12 cm., one 11.8 cm. in diameter, the larger presented nearer.
Series 2b	Two circles, in center of screen, one circle 12 cm., one 11.8 cm. in diameter, the smaller presented nearer.
Series 3a	Two circles, each 12 cm. in diameter, one in the center of the screen, one 1 cm. above the center of the screen, and 5 cm. out toward the outer edge of the tracks, the latter presented nearer.
Series 3b	Two circles, each 12 cm. in diameter, one in the center of the screen, one 1 cm. below the center of the screen and 5 cm. in toward the center of the tracks, the latter presented nearer.
Series 4	Check series on Series 1.

Monocular Series

Series 5	Series 1, each eye separately
Series 6	Series 2a, each eye separately
Series 7	Series 2b, each eye separately

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[1] Our later experiments at 195 meters in which the threshold values were practically the same as in this experiment indicated that we had successfully eliminated accommodation as a factor in the judgments.

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Series 1 to 4 were binocular. Series 1 was designed to determine acuity of visual perception of distance under these conditions when the two circles were equal in size and placement. Series 2a and 2b were planned to determine the influence of size of retinal image. Series 2a was to determine whether making the farther circle almost imperceptibly smaller without the knowledge of the observer would tend to influence the observer to make more correct judgments than in Series 1. The size of the smaller circle was by the observation of adult observers equated to the apparent size of the standard circle at four centimeters back of the standard distance. Series 2b was designed to determine whether making the nearer circle smaller than the farther would tend to make the judgments harder and more confused than in Series 1. Series 3a and 3b were to enable a study of the influence of linear perspective. Would putting the nearer circle slightly up and away from the center tend to suggest nearness, and putting the nearer circle down and toward the center tend to suggest farness? The position of the circles was determined by equating the position with the linear perspective at four centimeters in front of and back of the standard, respectively, by two adult observers. Series 4 was a check on Series 1 to make sure that any changes in acuity during Series 2 and Series 3 were not due to practice or to physiological changes in the condition of the eye.

Series 5 to 7 were monocular. Series 5 was a series repeating the conditions of Series 1 with each eye separately. Series 6 repeated conditions of Series 2a with each eye separately. Series 5, 6, and 7, were intended to factor out the difference in influence of binocular vision on the acuity and to determine the influence of the two varied factors under conditions of monocular vision. All series were not presented to all sixteen observers.

Preliminary Experimentation with Children

The preliminary series were presented for two purposes; (1) orientation of the child to the experimental situation, and (2) determination of the diagnostic range of distance for use in the regular series.

The child was brought into the lighted room to familiarize him with the surroundings. He was taken around the room, but no attention was called to the apparatus. He was asked to stand on the chair in front of the apparatus; the boxes were at the extreme end of the tracks. The experimenter said, "Do you see these boxes?

Point to the box that is nearer to you.'' If the response was correct, the boxes were reversed in position, and the question was again asked. This time the experimenter told the child to put up the hand that was in front of the nearer box. If he succeeded with ease in these two instances, he was fixed comfortably in the chair and his head adjusted in the headrest so that he could just see the lighted areas. If necessary, the height of the apparatus was changed. The experimenter then demonstrated the ringing of the buzzer. She pulled down the shade and adjusted the boxes at 190 cm. (left) and 670 cm. (right). She then turned out most of the lights in the room, snapped on the lights in the apparatus, and told the child that she was going to turn off all the lights, but would turn them on again soon. (Except in the first preliminary series the lights remained off during the entire experimental period; the experimenter used a flashlight while making adjustments and this could not be seen by the observer on account of the drawn shade.) She said, ''When I pull the shade up you are going to see two lights and I want you to look at them carefully.'' The shade was pulled and the lights exposed. The experimenter said, ''I want you to think about which one is nearer to you. Now I am going to push the stick that is in front of the nearer light and you see what happens.'' She placed her hand over the child's left one, and pushed. She said, ''See! I pushed the stick in front of the nearer light and a red light came. A red light always comes when we push the stick in front of the nearer light. Now I'm going to let you try it.'' She commended the child and pulled the shade, then reversed the boxes. In this instance she told the child she was going to let him try alone, that he ''must push the stick in front of the nearer light.'' If he was successful she said, ''That's right. You pushed the stick in front of the nearer light.'' If the child was wrong she said, ''No, the red light won't come if you don't push the stick in front of the nearer light.'' She then changed the boxes so that the nearer box was on the other side. She again demonstrated, saying that the nearer light was on ''this'' side now, and told him to push the stick in front of it. She continued to test the child at this distance until he had made the correct judgment three successive times. The nearer box was not always alternated in position, however. She then tested him at the following distances:

Left Box	Right Box
595 cm.	315 cm.
315 cm.	595 cm.
515 cm.	595 cm.
505 cm.	535 cm.
535 cm.	505 cm.
505 cm.	520 cm.
505 cm.	495 cm.
520 cm.	505 cm.
593 cm.	505 cm.
590 cm.	505 cm.
505 cm.	590 cm.
505 cm.	495 cm.
515 cm.	505 cm.
505 cm.	517 cm.

If the child was slow in his first reactions to the situation he would, in all probability not be able to go this far the first day. As soon as he showed signs of fatigue the experiment was stopped and this series was completed on the following day. If he did well consistently in all these distances, subsequent series similar to this in arrangement, but having smaller differences in distance, were tried out at various intervals. These preliminary series were continued until the experimenter had gained a good idea of the distance from the standard at which the child was right approximately 80 to 90 per cent of the time. This distance was termed x distance and constituted Position 1 (x distance nearer than the standard); one-half this distance constituted Position 2 ($\frac{x}{2}$ distance nearer than the standard); in Position 3 both boxes were placed at the standard distance. Position 4 was $\frac{x}{2}$ distance farther than the standard and Position 5 was x distance farther than the standard. The positions may be summarized as follows:

Position 1	One box x distance nearer than standard distance
Position 2	One box $\frac{x}{2}$ distance nearer than standard distance
Position 3	Both boxes at standard distance
Position 4	One box $\frac{x}{2}$ distance farther than standard distance
Position 5	One box x distance farther than standard distance

Preliminary Experimentation with Adults

The same process of preliminary experimentation was followed with the adults except, of course, it was not necessary to take care that the adults develop no fear. The adults reported difficulty and assurance on a double scale of three; degree of difficulty was indicated by 1 = easy; 2 = fairly easy; 3 = hard; and degree of assurance by 1 = sure; 2 = fairly sure; 3 = doubtful; a guess was reported as such.

It was necessary, of course, that the experimenter watch carefully that the observer's results later in the regular series corresponded to those she had predicted from the preliminary series. If the experimenter had not judged the observer's approximate acuity correctly it would be necessary later to begin the series again. This was necessary in only two cases, in one of which the first judgment eventually proved to have been the right one.

Experimental Series

Method of Observation.—Observations in the regular series were made in the same manner as in the preliminary series excepting for the period of five to ten minutes necessary for dark adaptation. In the three monocular series the observer wore a mask extending from the forehead down to the upper lip; the eye not in use was kept closed and covered by an oculist's gauze and cotton pad.

Order of Presentation.—The method of presentation used in the regular series was similar to the method of constant stimulus differences. As has been pointed out, five distances were judged throughout, but these distances varied with the acuity of the observers; each position occurred one-fifth of the time. The stimuli were presented in pairs, and the observer was told to judge which was the nearer of the two stimuli. These constitute the first deviations from the method of constant stimulus differences: (1) The stimuli were presented simultaneously and compared, rather than presented successively and the second judged in terms of the first; (2) the observer could make only one type of response, he had to indicate which one was nearer; he could not say that one was farther nor could he say that he was doubtful; (3) four-fifths of the time the observer knew when he was right, because he saw the red light; when two equal distances were presented neither of the circuits to the red light was opened. The above changes from the established method of constant stimulus differences were necessary because of the following reasons: (1) A child's interest in an experiment must be motivated, particularly in an investigation that means constant experimenting over a long period of time. Therefore the motivation had to be so devised that it would not only help the child comprehend the difference between success and failure, but would make success agreeable. (2) A child can not be depended upon to note a sensation and remember it to compare it with a subsequent sensation. Judgment must be made directly. Therefore the stimuli had to be presented simultaneously rather than successively. (3) A possibility of several responses is confusing to a child. If he had been allowed to judge a stimulus to be nearer, or farther, or doubtful, his response probably would not have been considered so carefully as it was when there was only one possible response. This response was connected with a definite movement on his part so that as many associations as possible could be formed and the response made as automatic as possible.

Because some of the observers were very young it was necessary to have many short series rather than a smaller number of long ones. In Series 1, accordingly, twenty-five judgments were made at a sitting, and in Series 2a, and 3a and 3b, only twenty. This resulted in an experimental period of about fifteen minutes. Since the children had to be brought from a building two blocks away the experiment took approximately half an hour. Because the judgment periods were so short, the experiment required about five months spent for each child; he observed every day he was in school.

The series were so arranged that each position was presented five times a day; these were divided equally between right and left judgments. The order of presentation was haphazard, although constant in the sense that each observer made judgments in the same order as all the others. Ten trials were arranged, twenty-five judgments in a trial. Trial 1 was identical with Trial 8, Trial 2 with Trial 6, Trial 3 with Trial 9, and Trial 4 with Trial 7; Trial 5 was like Trial 10, except for a reversal of the left and right positions in the last five judgments, in order to equate left and right in the whole series (Figure 6). Records were kept on special blanks; these read from left to right. As soon as five trials had been given in a series the mean number correct in any one position at one trial, and the standard error of the standard deviation were computed. Experimentation was stopped when the standard error was less than one-third the standard deviation of the mean, except when some uncontrollable cause, such as the close of the term, or departure of a child, intervened.

IOWA CHILD WELFARE RESEARCH STATION
State University of Iowa
Iowa City, Iowa

Name............Number 384............ Group....2.... Sex....F.... Date........27-10-19........
Series....1.... Stimuli........499-511........ cm.....12.... Date of Birth........23-7-29........
......................cm.. Age............4-2-21

Updegraff Distance Perception
Trial 1

L 1		L 2		R 3		R 4		L 5	
L 4		L 3		R 2		R 5		R 1	
L 5		R 4		L 1		L 2		R 3	
L 4		R 5		L 3		R 1		R 2	
L 5		R 3		L 1		L 2		R 4	

Stimuli	Left		Right		Total	
	+	—	+	—	+	—
1( )						
2( )						
3( )						
4( )						
5( )						

Figure 6

Record blank for Main Experiment. Reads from left to right

L_1=Position 1 on the left—Standard on right

R_3=Position 3 on the right—Standard on left

R_5=Position 5 on the right—Standard on left

Series 1 was completed before Series 2a was begun. Then Series 2a, 2b, 3a, and 3b were all begun at the same time, five judgments in each series required in a day, and in the order, 2a, 3a, 2b, and 3b. This order was varied sufficiently often that the observers, if they could distinguish, could not predict. These four series were mixed in this way so that it would be almost impossible for the observer to get any clue to what was being done; he was forced to judge only on his perception. The fact that there was not a red light on

Position 3 also guarded against his getting clues. Each of the series was completed as a whole.

There was no time limitation on the judgment because hurrying the children would have greatly reduced the reliability. The average time required for the judgment of each individual was obtained.

In the procedure, therefore, it was possible for the observer to judge distance with the help of the size of retinal image, mathematical perspective, intensity differences, and stereoscopic vision. If acuity had been determined with the help of all four of these, and then any one of them varied, the resultant change might be assumed to be due to the factor that was varied. Binocular stereoscopy may be ruled out entirely in the monocular series. It is probable that such slight changes in intensity as are found here have no influence. In order to prove this, four of the observers made series of judgments on intensity difference; none of them was able to perceive intensity differences at less than fifteen centimeters distance either side of the standard. Since in no case was so great a difference in distance necessary, intensity may probably be ruled out as a factor.

SECONDARY EXPERIMENTS

After a comparatively large number of observations had been made in the Main Experiment it seemed possible to make preliminary studies of other aspects of the problem of visual perception of distance than the ones on which experimentation had been carried on intensively. Therefore two techniques were devised, one for studying distance perception at long range and one for studying distance perception at short range.

SECONDARY EXPERIMENT A

The object of this section of the investigation was the development of an apparatus and a procedure for the determination of (1) the keenness and accuracy of the young child's perception of differences in distance when two objects are placed at a considerable distance from him and (2) the effect on this accuracy of the change in size of one of the objects.

The setting chosen for the experiment was a large pasture about five miles from Iowa City. Its particular qualifications for the experiment were a regularity of contour with a very gradual and slight rise as the distance from the observer increased (about 1 m.

in 195 m.) and a resultant lack of background for any objects placed at the crest of the rise.

Apparatus

The stimuli whose distances from the observer were to be compared were two beaverboard discs 77.1 cm. in diameter, and one disc 75.1 cm. in diameter, painted black and fastened to poles 2 cm. by 2 cm., 2.5 m. high. The poles were not painted, but left the natural white pine. Fastened to the other end of each pole was a flat, pointed iron rod (20.5 cm. long) as wide as the pole, to make pushing the pole into the ground easier. At the time of the experiment the grass in the field was about fifteen centimeters high. The observers were taken to the field on sunny days only; the sun was always high in the sky, and at the back of the children as they stood making their judgments.

In preliminary experiments with adults the relative merits of black and white discs were tried out; there was a constant error in favor of the black, since its contour was much more definite. It was therefore believed that the black would make the child's judgments easier for him, and therefore more reliable. There was no apparatus specifically for the observer.

Method

Following out the principle involved throughout this entire investigation, a pair of objects was presented, the nearer to be indicated by the observer; the principle of comparison with a standard distance was also followed. One-half the time two discs of equal size were presented; one-half the time one disc was smaller than the other, and in this case the larger disc was always the nearer one. The situations presented for judgment when the discs differed in size duplicated the series when they were of equal size.

The standard distance was 194.56 m. (638 ft. 4 in.) from the observer, visual angle of 0° 13′ 26.7″. Compared with one of the discs at the standard was a disc 6 m. nearer, angle of 0° 13′ 59.18″ (Position 1), 3 m. nearer, angle 0° 13′ 39.3″ (Position 2); and 3 m. farther away, angle of 0° 13′ 14.48″ (Position 4); and 6 m. farther away, angle of 0° 13′ 2.04″ (Position 5) (Figure 7). The series of pairs were divided equally as to right and left placement, in haphazard order. The distance between the two lines along which the

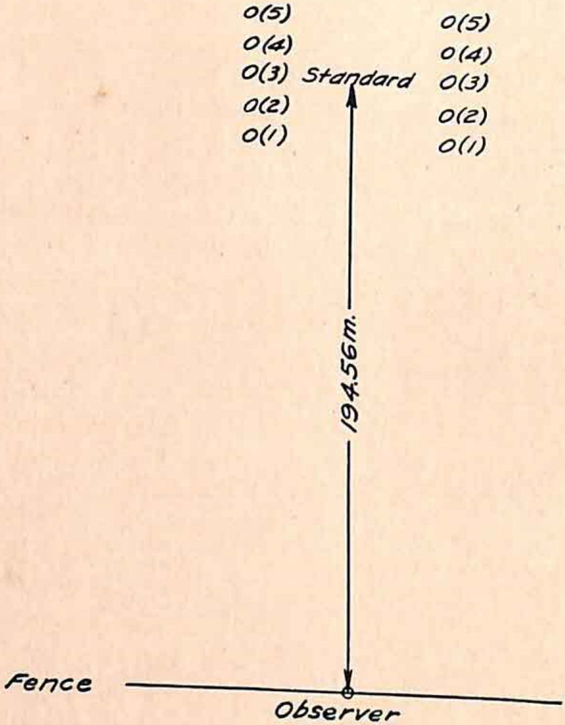

Figure 7. Secondary Experiment A. Diagram of positions.

stimuli occurred was 331 cm. The positions may be summarized as follows:

Position 1	6 m. nearer than standard distance
Position 2	3 m. nearer than standard distance
Position 3	Standard distance
Position 4	3 m. farther than standard distance
Position 5	6 m. farther than standard distance

The smaller disc made an angle of 0° 13′ 6.2″ at standard distance, 0° 13′ 18.62″ 3 m. nearer, 0° 13′ 31.04″ 6 m. nearer; at 3 m. back of the standard the angle was 0° 12′ 53.78″, and at 6 m. back of the standard 0° 12′ 41.38″. The order of presentation was as follows:

	Left of Observer			Right of Observer		
	Disc	Distance	Position	Disc	Distance	Position
1.	Large	194.56 m.	3	Large	188.56 m.	1
2.	Large	194.56 m.	3	Large	200.56 m.	5
3.	Small	197.56 m.	4	Large	194.56 m.	3
4.	Small	194.56 m.	3	Large	188.56 m.	1
5.	Large	191.56 m.	2	Small	194.56 m.	3
6.	Large	197.56 m.	4	Large	194.56 m.	3
7.	Large	194.56 m.	3	Small	200.56 m.	5
8.	Large	191.56 m.	2	Large	194.56 m.	3

Eight judgments were required of each observer. When the experiment was first started the experimenter had thought it might be possible to secure sixteen judgments in one series from each child. The series was balanced accordingly. The first day of experiment proved unquestionably that only eight judgments were possible. The situations with which these first children had been presented, that is, the first eight of the sixteen, were not, then, balanced. It was therefore necessary to retest these six children on the revised series; this was done after a lapse of about two weeks.

For the convenience of the assistant who moved the discs, stakes were placed at the ten places in which the discs might be located, and the ground softened. The poles were always pushed in to full length of the iron. The field of vision of the observer, then, consisted of a long expanse of green and two black discs seeming to stand about two feet above the level of the green, (this effect produced by the invisibility of the poles on which the discs were fastened). At the extreme left of the field of vision could be seen the very top of a tree which was about 300 meters back of the discs. This tree was far out of the line of regard on the discs and was not useful in comparing the distances of the discs.

Besides the experimenter two assistants were necessary: one to manipulate the discs, and one to hold the attention of the children who were not observing at the time.

As a preliminary to the experiment the children's knowledge of the necessary distance vocabulary was tested; four objects were placed in a testing room, directly in front of the child, and he was asked to indicate the nearer one of each of six pairs. All the children but one responded without hesitation, correctly; that one understood the word "closer" and immediately carried over the relationship when it was explained to her. When all the children had completed the preliminary test they were taken to the field in groups of three or four. The total time of absence of each group from the preschool laboratory ranged from one to one and one-half hours. The experimenter arranged the groups so that there was always at least one child with whom she had worked during the preceeding year. In addition, she had taken pains to be with the whole group a sufficient time for all the children to feel perfectly familiar with her. The whole experiment was considered a most enjoyable game, and although each child realized the necessity for seriousness and effort on his part during the experimentation, the rest of the time was regarded as more or less of a pleasure outing.

The actual method of the experiment was as follows: The automobile was drawn up at the far side of the road and the children's attention was engaged in some activity on the side of the automobile away from the experimental field. When the apparatus was in readiness for the first judgment the experimenter took one child by the hand, and, leaving the other children in the care of the assistant, led him to the spot where he was to stand in order to make his judgment. After he was standing quietly, she said to him, "Do you see those two black circles? I want you to look at them carefully. Think about which of them is nearer to you. . . . Now put up the hand in front of the one that is nearer to you." She always commented with approval on the judgments, except in a few cases where she thought that the judgment had not received sufficient consideration. When the judgment had been made, the experimenter took the child back to the group and brought another to make the judgment. When all the children had judged, a signal was given and the assistant placed the discs for the next judgment, during which time the experimenter coöperated with the second assistant in keeping the children's attention away from the field. The same procedure was followed throughout except that it was found necessary to make an insertion in the instructions for the last seven judgments, in order to guard against the child's always choosing the same side. Since their attention had been carefully distracted from the fact that the position of the discs were being changed, some of the children inferred that they had not been changed and judged alike throughout. Accordingly, just before the pause this sentence was inserted: "Remember that the nearer one is not always on the same side." The children to whom this caution was not given were allowed to finish the series, but were brought out at a later date and the experiment repeated with the revised instructions.

SECONDARY EXPERIMENT B

The following apparatus was designed with the object of developing a method for the study of visual perception of distance of young children at one meter. The short distance in question naturally distinguishes this method from the others, since in judging at a short distance individuals are helped to a considerable degree by the muscles of accommodation and convergence, as well as by the size of the retinal image. Mathematical or linear perspective is here of less importance.

Apparatus

This apparatus was an adaptation of one used by Köhler (19) in part of his study on the distance and size perceptions of chimpanzees.

A whole view of the apparatus showed a large rectangular enclosure having a peep-hole in the front end by which a child could look through a window in a partition which divided the enclosure in half.

On the long side to the left of the peep-hole were two curtained openings. The enclosure, (1 m. wide, 2 m. long, and 1.23 m. high) was made of beaverboard reinforced by wooden frames; there was no top. The front end of the enclosure had in its center an opening (12 cm. wide) which extended from the floor to the wooden frame that reinforced the top of the sides. At each side of this opening was a grooved board. Crosswise between these grooved boards could be inserted strips of wood (2 cm. thick and 2 to 5 cm. wide) that were so cut that they fitted tightly into the grooves and could be moved up and down in the opening. Thus when the opening was completely filled with these small boards the front of the box presented a solid appearance. When one board was taken out there remained an opening 12 cm. in length and as wide as the board removed. Since the boards could all be pushed up and down, an opening of any height might be made in the middle of the front at any distance from the floor. Fitting a rectangular tube 17 cm. long, 12 cm. wide, and 5 cm. high into an opening at the desired height produced a peep-hole in the front end.

The long side at right angles and to the left of the front end contained two large curtained doorways, 83 cm. wide and 88 cm. high;

between the doorways, that is, at the middle of this long side, was a strip of wood 8.5 cm. wide. The back end of the enclosure and the right side were solid. A partition parallel to the front and back ends, joining the left side at the strip of wood and the right side in a groove directly opposite, divided the enclosure exactly in half. This partition contained an opening and adjustable boards identical with those in the front end, except that this opening was 25 cm. wide. During the experiment the boards were so placed in the partition that the gap left was large enough to preclude the possibility of the child's seeing its upper and lower limits; he could, however, see the sides of the opening. A centimeter scale was tacked on a long narrow flat board running the length of the top of the box and fitted into blocks fastened to the front, the partition, and the back.

The box was painted a flat neutral brown; the curtains were yellow. For convenience the enclosure was made collapsible; screwed into each of the four sides, four on each part 10 cm. from the top and bottom, were parts of 5 cm. hinges; when the parts of the hinges were fitted together and a hinge-pin inserted the four sides were held together. Accuracy of position was insured in two ways; four right-angle irons were fastened to each of the long sides; the two short sides and the two long sides had to be parallel in order that the long stick holding the measuring scale might fit into its support. The partition slid from the top into the grooves made to hold it. (Figure 8) In addition, two yellow balls 8 cm. and 5 cm. in diameter respectively, and two soft, well stuffed pillows were used.

Method

The method in general was based on the fact that an observer looking through the hole in the front end of the box could see any object that fell from the top to the bottom of the enclosure in his line of vision; by judging whether the object had fallen in front or back of the opening in the middle of the partition, he could judge whether the object had fallen into the front or the back room.

The first day the child saw the apparatus the experimenter brought him from the playroom, saying that she wanted him to see her "house." She brought him into the experimental room and after shutting the door said, "See, here is my house. I want you to see it." The child usually ran around it or stood looking for a

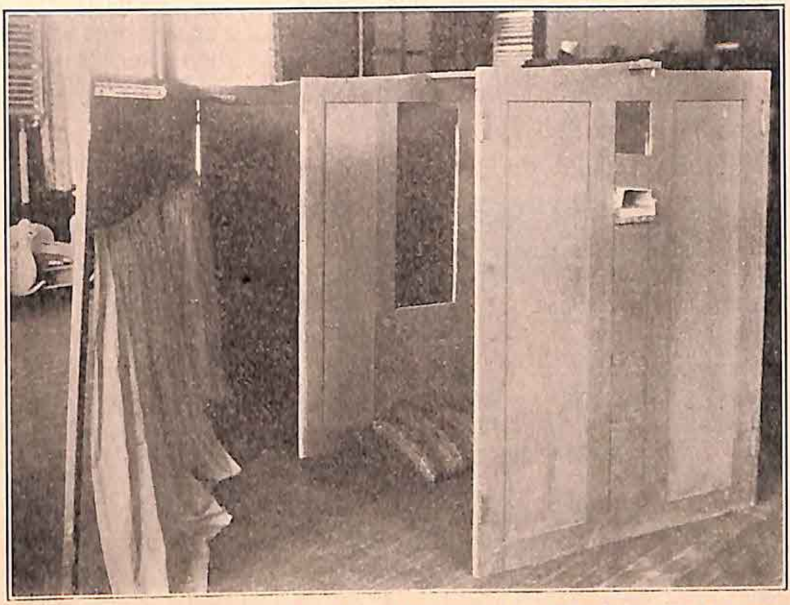

Figure 8. Apparatus for Secondary Experiment. The left side is opened to show the construction of the enclosure.

minute. The experimenter said, "Here is the front door and here is the front room." while she held the curtain so that the child might see into the room and might go in if he wished. If he went in she let him look around. Many of the children looked into the space back of the partition and sometimes made a move to step through. In any case the experimenter soon said, "Now if you will come out, I shall show you something else. Here is the back door and here is the back room." After the child had looked into it for a minute or so the experimenter said, "Now if you will come out I'll show you the window." She then took him around to the front end and showed him how he could see into the house through the window. She said, "Tomorrow we'll play a game with my house."

When the child was brought into the room the next day the experimenter said, "Now you look through the window. I am going to drop a ball into the house. You watch and you'll see it. Then run get it quickly. See whether it falls in the front room or the back room." She stood exactly at the partition, dropped the ball from one of five positions, and immediately stepped back. There was no automatic device for dropping the ball. However, after considerable practice the experimenter felt herself to be fairly accurate in dropping the ball in a straight line. The ball was held so that a raised line around its equator directly corresponded to the specified scale along the top of the apparatus; the thumb and third finger grasped the ball directly opposite to each other in the center of the ball, at the extremes of the plane at right angles to the above mentioned line. The pillows, one in each room, were placed so that the ball would fall into the middle of the pillow, thus deadening the sound. In order to get the ball the child had first to decide whether the ball was in the front or the back room then to walk around to the proper doorway and raise the curtain (Figure 9). If he had judged correctly he was allowed to get the ball and hand it to the experimenter. Frequent commendation was given. If the child judged incorrectly the experimenter picked up the ball, saying, "I'll get the ball. When you find it you may get it, but when you don't find it I pick it up." Then she said, "Now run back to your window and look at the ball again. See which room it's in. Here it comes." These were the instructions throughout the rest of the

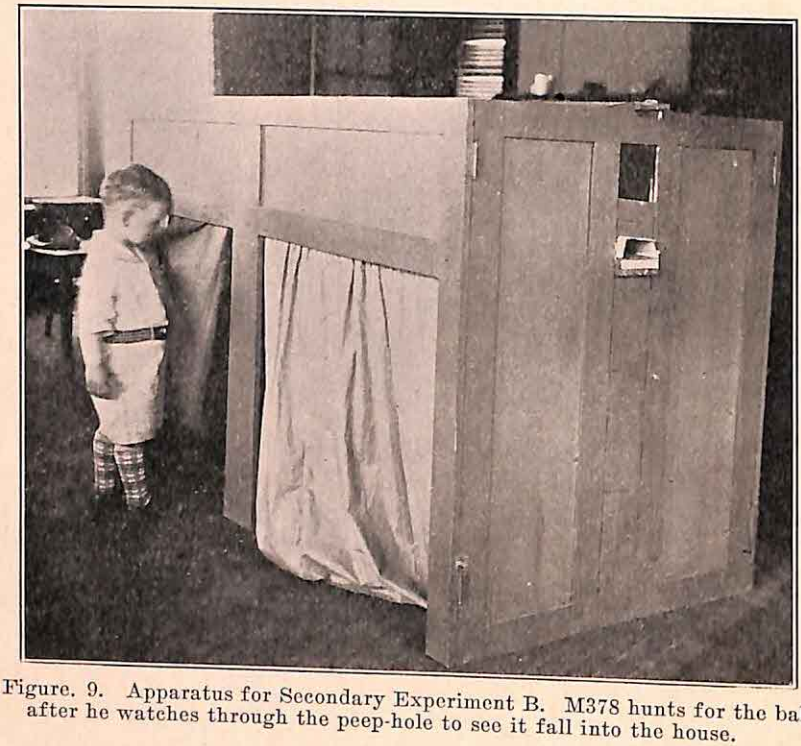

Figure. 9. Apparatus for Secondary Experiment B. M378 hunts for the ball after he watches through the peep-hole to see it fall into the house.

experiment. After the six or eight trials for each day had been completed, the child was given the ball to play with for a while, and the experimenter offered to bounce it with him.

During two months of experimentation electric lighting was necessary for four days.

Method of Presentation.—There were three series besides the preliminary series of experiments. There were three trials in Series 1 and 2, and one trial in Series 3.

In the preliminary series, designed to find out approximately at what distance all the children were successful, there seemed little doubt that distances 43 cm. back and front of the standard (the distance 1 m. of the partition from the child's eye), 21 cm., and 14 cm. were readily distinguished. Therefore all distances used subsequently were smaller than these.

Series 1

There were six positions in Series 1; the larger ball was used throughout. The positions of the equator line of the ball were:

5 cm. back of standard distance
7 cm. front of standard distance
9 cm. back of standard distance
7 cm. back of standard distance
5 cm. front of standard distance
9 cm. front of standard distance

Series 2

There were seven positions in Series 2; both balls were used. The small ball was used nearer than the standard distance directly after the large ball had been dropped from the back of the standard distance, in order to determine whether there would be a tendency to think the small ball back of the standard. This was immediately followed by the large ball back of the standard. The small ball was also used directly after the large ball in front of the partition, to determine whether this strengthened accuracy back of the standard. The distances used were the same as in Series 1. The seven positions of the equator line of the ball were:

5 cm. back of standard distance, large ball
7 cm. front of standard distance, small ball
9 cm. back of standard distance, large ball
7 cm. front of standard distance, large ball
5 cm. back of standard distance, small ball
7 cm. back of standard distance, small ball
5 cm. front of standard distance, small ball

Series 3

Series 3 was performed entirely with the smaller ball. One trial only was necessary for this series, as only two positions were possible, one in front of the partition and one back of it. The positions of the equator line of the ball were:

3.5 cm. front of standard distance
3.5 cm. back of standard distance
3.5 cm. back of standard distance
3.5 cm. front of standard distance
3.5 cm. front of standard distance
3.5 cm. back of standard distance

With one group of eight children trials in Series 1 and Series 2 were given alternately. In the other group of eleven children Series 1 was completed before Series 2 was begun. This was due to a misunderstanding, the two groups having two different experimenters. After Series 1 and 2 were finished the records were examined, and if, at any one position, the record at any one of the three trials differed from the record at the other two, the same position was tried again in a check series. These check series were continued until either a success or a failure exceeded by at least two responses. The final score on any one position, therefore, was a plus or a minus, either the child could perceive the difference, or he could not. Series 3 was presented after the check series on Series 1 and 2 and, if necessary, was followed by a check series of its own.

A Check Experiment With Adults

In order to compare the responses of these children with those of adults the same series were presented to sixteen adults.

There were some slight changes in the method in order to facilitate experimentation wherever possible without changing any vital part of the experiment: (1) The adults did not have to obtain the ball; they simply reported "front" or "back"; (2) Since the adults were capable of a longer period of experimentation, Series 1, 2, and 3 were gone through without a break. If any mistakes occurred, the final score was obtained by giving experimentation at this position (intermixed with others) until failure or success predominated to the extent used as a criterion with the children. (3) Adults were asked to introspect, and were particularly asked if they thought the balls always looked the same, and if any of the judgments seemed easier than others.

CHAPTER IV

ANALYSIS OF THE EXPERIMENTAL RESULTS

PRELIMINARY EXPERIMENT:

A STUDY OF CHILDREN'S CONCEPTS OF RELATIVE DISTANCE

It will be remembered that the preliminary experiment was a study of the vocabulary of two-, three-, four-, five-, and six-year-old children, as it bears on the comparative aspect of distance, i.e., (1) "nearer," (2) "farther," (3) "closer." Each child pointed to the nearer of the two cubes placed within a distance of one meter from him, horizontally, and at a later time, pointed to the farther one. Later, the same words were applied to distances up and down.

GENERAL REACTIONS TO THE EXPERIMENTAL SITUATION

At first glance it might seem that there was nothing inherent in the method of presenting this experiment that would make the children particularly interested in coöperating or that would elicit the desired response naturally and consistently. On the contrary, one section of the apparatus made a decided appeal to the young child's joy in the unexpected: because the moving screen would suddenly reveal a new position of the recognized blocks, a child would continue enthusiastic throughout the series. "It's just like a show, isn't it?" commented one four-year-old child, and "You have a lot of fun with this, don't you?" On account of the child's interest, the experimenter was able to ask a question about the nearer or farther block and receive a simple and natural answer without seeming to make the situation a series of questions; the latter would immediately have destroyed all spontaniety and interest. In the case of the very young children who could not understand why they should point to the blocks more than once, and who, therefore, spent more time on any one judgment than did the older children, the series was too long and fatiguing. An enlightening study might have been made of the various reactions of the children upon realizing that the screen was provided to prevent their seeing the movements of the experimenter. Some children tried all manner of means to peek behind the scenes, some openly, some covertly. Others artfully tried to ask questions about the blocks before the screen was removed. In contrast to them were the children who wanted to receive all the thrill possible from the surprise and were content to wait until the screen was pulled aside.

ANALYSIS OF THE DATA

Tendencies in growth may be noted from an examination of Table 1, although the number in any one age group is too small to be relied upon absolutely. To consider first the recognition of horizontal distance, it can be seen that there is a steady rise in the percentage curve denoting successful response to the two words "nearer" and "farther." None of the children from two and one-half to three years of age knew either word, and all of those six years of age readily responded to both. In comparing the curves for the two words (see Figure 10), it is noticeable that the "nearer" curve rises later than the "farther" one, although they meet during the fourth year.

Table 1

Percentage of Successful Responses to Words Concerning Relative Distance by Fifty-One Children from Two to Six Years of Age Given the Preliminary Experiment

Age	Children in Age Group	Successful Responses			Children in Age Group	Successful Responses	
		Horizontal				Vertical Up	Vertical Down
Years Months Days Years Months Days		Farther	Nearer	*Closer		Nearer and Farther	Nearer and Farther
		Per Cent	Per Cent	Per Cent		Per Cent	Per Cent
2–6–0 to 2–11–29	4	0.0	0.0	0.0			
3–0–0 to 3– 5–29	2	50.0	0.0	0.0			
3–6–0 to 3–11–29	4	75.0	50.0	0.0			
4–0–0 to 4– 5–29	4	75.0	50.0	25.0			
4–6–0 to 4–11–29	11	72.7	81.8	9.0			
5–0–0 to 5– 5–29	7	100.0	85.7	0.0	10	70.0	70.0
5–6–0 to 5–11–29	11	100.0	90.0	10.0	7	85.7	57.1
6–0–0 to 6– 5–29	8	100.0	100.0		8	75.0	50.0
					8	100.0	100.0

* Closer was presented only after failure on nearer.

Examination of the individual records of the children under

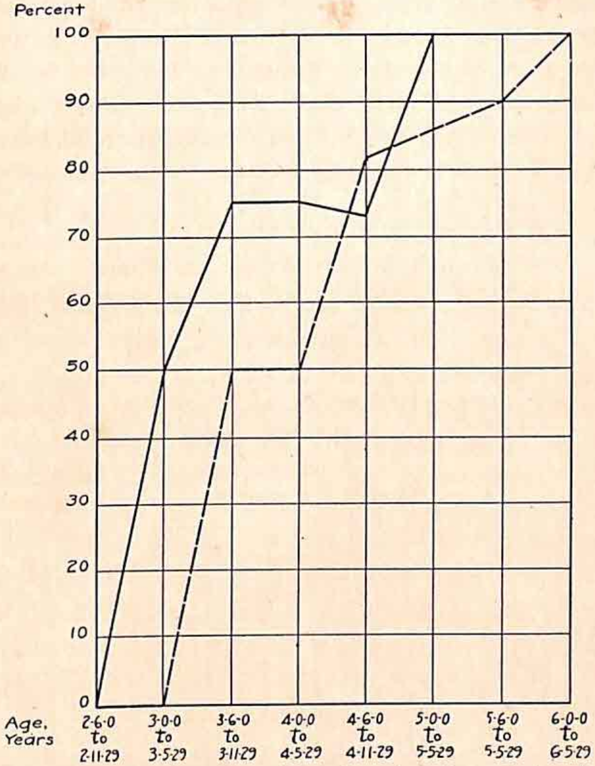

Figure 10. Preliminary Experiment. Per cent of children understanding the words nearer (——) and farther (— — —) by age groups.

four years shows that there was only one child who unquestionably understood both "farther" and "nearer," and six observers who did not comprehend the instructions. One child of three years and eight months who understood "farther" at all distances except those nearest to her, possibly connected "farther" with some meaning of absolute farness. "Farther" seemed to have a more definite meaning for these children than had "nearer." Two children of over four and one-half years did not understand any of the words. The majority of other children of this age, however, were little confused. At this age, particularly, it was brought out that lack of understanding of the meaning of the words did not mean lack of understanding of the underlying concept of distance. Some of those who failed to respond correctly to "nearer," succeeded on "closer." When the experimenter supplied "to you" or "from you" she seldom aided the child thereby. A few of the children inquired, on their own initiative, "nearer to me?" or "Farther from me?"

The two paired positions at the end of the series which placed both blocks equally distant from the observer, were of discriminative value. Some observers were decidedly more suggestible than others. All of the children younger than four years indicated one of the blocks as nearer or farther. This in all likelihood implies that the children obligingly complied with the experimenter's request rather than that they did not really perceive the equal distance of the cubes. About one-half of the older children said, "They're the same," or made some like statement of a positive rather than a negative nature.

Responses to "nearer" and "farther," applied to distance up and down (see Table 1), revealed the fact that this use of "nearer" and "farther" was not so readily understood by children four years of age and above (the only ages tested), as were the same words used in respect to horizontal distance. This is interesting in the light of Mrs. Moore's comment on the development of distance perception in her son, referred to in Chapter I. By the age of six and one-half years none of the children seemed to have trouble in making the judgments.

SUMMARY

1. The words "nearer" and "farther" were in the passive vocabulary of all children of approximately six years and were recognized by a large majority of four-year-old children.
2. No children three years of age or under were able to understand the use of these two words in the experimental situation. This is not taken to mean that the children had no visual perception of distance.
3. It would seem that between the ages of three and six an understanding of the meaning of these words is acquired.
4. "Farther" was learned before "nearer."
5. The idea of the personal reference of "nearer" and "farther" was taken for granted by most children.
6. The use of "nearer" and "farther" when applied to distance up and down was not so readily understood as when the same words were applied to horizontal distance.
7. The words "nearer" and "farther" may safely be used in an experimental situation for four-year-olds, providing each ob-

server's comprehension of the word is tested by some such method as the above.

MAIN EXPERIMENT

This experiment, to recall it briefly, was carried on in a dark room; the observers judged the nearer of two lighted circular fields, 12 cm. in diameter, which varied in position around a distance of 505 cm. from the observer. There were sixteen observers, ten children between the ages of four years, three months and four years, eleven months, and six adults, graduate students. The chronological age, intelligence quotient, and Marston[2] introversion-extroversion rating of each child are shown below:

Child	Chronological Age	Intelligence Quotient	Marston Introversion-Extroversion*
F384	4– 2–21	102	44
F200	4– 2–28	105	44
M382	4– 4– 2	106	46
F307	4– 4–25	132	76
M358	4– 5–18	113	77
M269	4– 6–18	100	55
M297	4– 7–16	116	77
F367	4– 8– 0	106	61
F192	4– 8– 4	137	73
F381	4–10–25	117	59

* Normal balance 50-70.

The results of the optical examinations of the children, by the skiascopic method, show that the variations come within the normal range.[3]

Five of the six adults wore glasses which corrected to normal and which had been fitted within a year of the time of the observations made in this experiment. The one observer who constituted

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[2] Marston, Leslie R.: The Emotions of Young Children: An Experimental Study in Introversion and Extroversion. Univ. Iowa Stud., Stud. in Child Welfare, 1925, 3, No. 3, Pp. 99.

[3] Results of the optical examinations by the skiascopic method:

F384 —R. S—0.50
L. S—0.50
F200 —R. S+0.50
L. S+0.75
M382—R. —0.25
L. Emmetropic
F307 —R. S+0.50○C+0.25ax90
L. S+0.50
M358—R. S—0.50
L. S—0.25○C—0.25ax90
M269—R. S—0.25○C—0.75axo
L. S—0.25○C—0.75axo
M297—R. S+0.25
L. S+0.50
F367 —R. S+0.25
L. S+0.50
F192 —R. S+0.25○C+0.50axo
L. S+0.25○C+0.25ax120
F381 —R. C+0.25axo
L. C+0.25axo

the exception (F) reported normal vision, her eyes having been tested during the year.

To the children of this age, four years, an experiment in the dark room is a pleasing novelty rather than a dreaded experience. Precautions had been taken to avoid alarming the children in any way, but even these were not proof against fear in the few younger children, three-year-old children who were introduced to the apparatus. Only two of the children reported as observers in this experiment gave any evidence of even considering the unusual experience of the dark room; M382 said on the first day of his regular series, "I'm not scared of the dark, am I? I just go down and don't cry." Also on the first day of the regular series, F381 volunteered, "I'm not afraid of the dark, is I?" Four months later she made the statement, "I'm not afraid of the dark."

In fact, it is known to those experimenting with very young children that the direct question may be an effective means of covering up the causes underlying a child's actions, and may destroy all chances of securing the child's coöperation in report. Introspective evidence gained by questioning a child concerning his feelings, motives, and actions, is unreliable. However, if the experimenter has the confidence of the child and is quick to act upon cues, enlightening information may be obtained.

Before experimentation was begun the possibility of keeping the interest of the children throughout the many series was a somewhat dubious one. It was feared that an experiment of this type, continuing over so extended a time and requiring experimental periods in themselves comparatively long, might not be conducive to reliable results. Not only was there necessity for retaining the child's interest in the experiment itself, but it was essential that the performance compensate for possible dissatisfaction at leaving the other children and other interesting activities. By the time the experimental routine was well established it was clear that the motivation was sufficient to carry over for a long period. The experiment which at first seemed a delightful novelty became part of the day's order; as such it was enjoyed not only because of the pleasures intrinsic in the operation of the apparatus but also for the fact that it involved repetition of the same activity and satisfaction in good performance. It was only natural that on some days the children showed less interest than was customary, in spite of the fact that the experimenter definitely avoided taking them from an absorbing occupation. That they felt free to express their disinterest at any time was evidenced by the fact that they informed the experimenter if the occasion arose. It was only infrequently, however, that any child stated early in an experimental series that he wished not to "play the game" on that day.

The apparatus itself contributed to a great degree in giving desirable motivation to the experiment. That the red light was a reward for success may be proved by glancing at almost any one of the record sheets for such exclamations as "Ha-ha! I got a red light!" "I'll betcha I get a red light," and "I wished I could have got it." Before experimentation there had been some doubt as to the complete efficacy of the two buzzers. Although the buzzers were necessary in order that the experimenter know just when the child pushed the levers, there was a possibility of their proving so attractive that the motivation of the red light would be somewhat lessened. As it turned out, the buzzers interested the children only in an incidental way. F384 named them "Bee" and "Paw", achieving thereby astonishing likeness to their sounds, but her efforts to "get the red light" were none the less enthusiastic. F307 often sang a tone to match the lower of the two but forgot this as soon as the experimenter told her to be ready. F367 occasionally pushed them simultaneously while the stimulus was being changed because "I like the mixed noise," but it was she who was the most vociferous in her disgust at failing to obtain the change in light, exclaiming "Bah!" loudly. Because the buzzers could be worked at any time they served as a diversion during change of stimulus. Since there was thus afforded considerable release of energy and a relief from inactivity, both of which are almost necessary in an experiment of this kind, they played a double role.

Intelligent interest in the experiment and apparatus was frequently expressed: "Where's the electricity?" "Where's the wires?" "How do the red lights connect?" "How do you make the shade go up?" "They both get red, don't they?" "What makes the red light?" "They make different noises, don't they?" Several of the children indicated that they knew the experimenter was definitely controlling the red lights. M358 once exclaimed, exasperatedly, "If you'd only leave them switches alone I could always get it!" And asked again, "Are you going to turn the switch?" (Since changing the switch made an audible click it was necessary for the experimenter always to click it, whether the position was changed or not.) On the other hand, F381, on noticing that the experimenter had inadvertently failed to fit the screen, leaving part of the lighted glass showing, informed her that there was a "piece of paper" that she ought to remove.

The stimulus lights further excited the imagination of some of the observers: "Say, there's two eyes over there and two in my face," was an observation by M382. M297 thought, concerning the change from a white to a red light, that "It looked like it was shutting one eye." To F200 "Those lights look like red balls and white eggs, don't they? Balls and eggs are round, and so are the lights, aren't they?"

The attempts of the children to judge the nearer light correctly represented real effort. As soon as the experimenter said, "Ready" conversation or other activity ceased and the eyes were focused on the spot where the lights would show when the curtain was raised. Although some children habitually took longer to make the judgments than did others, for the most part they judged to the best of their ability. The average amount of time necessary for each child to make his judgments ranged from 2.83 seconds to 6.50 seconds; most of the children took on some occasions exceedingly long times. F200, M269, F192, and F267 were all apt to consider a judgment for fifteen or twenty seconds if it seemed difficult. The experimenter received proof that her instructions had been understood when F384, questioned by an outsider in entirely different surroundings, was overheard to say, "You push on the stick in front of the light that is nearer to you." F200's wish to do well was indicated, "I think it would be better if you didn't mark the ones that weren't right." She inquired often, "Is this the one that's hard?" F307 exclaimed, "I'm getting lots of red lights, aren't I? 'Cause they're easy, aren't they?" And also, "Oh! I could just fall out of this chair! You didn't know I was so good, did you?" (That she was to some degree aware of the experimental nature of the proceedings could not be doubted after she commented, because she heard the experimenter writing during the series, "Gee, I got a lot of score that time didn't I?") F367, "I'll make this a red light, shall I? . . . Good! I want to make the last one a red light." It was she who ventured, in her desire for a very apparent difference in distance, "You couldn't push it clear to the end, could you?" Effort was evident: "I shut my eyes and thinked, and when I heard the curtain I woke up." (F307). "I thinked and

I got a red light." (M358). "I thinked hard on that one, Miss U." (F367). "I suppose the little kids don't know how to play this. I suppose I'm getting too many red lights." (M358). Conducive of sympathy was, "Sometimes its pretty hard to guess." There was also apparent some spirit of competition; "How many lights did Henry get this morning?" "Does Jane get as many white lights as I'm getting?" "I'll bet I'm better than Joe is." At times the desire to be successful became too strong and such warnings as "Next time I'm going to push down both sticks," and, "I have to push two sticks," were forthcoming.

When the experimenter attempted to suggest distance by varying the stimulus without varying the distance, there were some decided accusations from the children who showed that they did not agree with the placing of the red light. M358, after a failure, made protest, "You had that one towards this way, I seen it!" By F307 also, "That one was the nearest to me, too." M269 was quite definite: "That was the side that was the longer and it didn't have a red light; anyway, sometimes I get a red light when they're long." "This one looked like it was up in front of me and it wasn't." (F384).

That analyses of some sort were being carried through by the children was evidenced by some of their statements. F384 said frequently, to herself, "This one? No, this one." M297 explained that, "First I was going to do this one but then I thought it was this one." F367, "I want to think for a while," then under her breath, "We had that one, now we'll have this one." and "This one's not near to me. This one is near to me." Probably F381 was including right and left in her thinking, "The right hand and the left hand, and so this is the left stick. . ." M382 queried, "Why do you have this one over here all the time?"

Finally, these children were not passively accepting the experiment but were themselves doing objective thinking. Indicative of this are the following three observations, made at various times and all directed to the experimenter. F381, "If you were playing this game would you get all the red lights?" At times F384 became slightly irritated at her failures; she stated quite frankly, "Those lights aren't near to me. You just think they are." Her most incriminating accusation, nevertheless arousing sympathy, was, "If you can't tell which one of those lights is nearer, how do you think I can?"

Table 2

Total Number of Judgments for Each Observer in the Seven Series of the Main Experiment

Observer	Number of Judgments at Each Position								Total	
	Series								Seven Series	Five Positions
	1	2a	2b	3a	3b	5	6	7		
Children										
F307	50	15	15	15	15				110	550
F367	25	25	25	25	25	25			175	875
M358	25	25	25	25	25	25			175	875
F381	50	25	25	25	25	25	15		230	1,150
F200	50	10	10	10	10				90	450
F384	30	25	25	25	25	25			130	650
M297	25								25	125
M382	65								65	325
F192	50	20	20	20	20	20			130	650
M269	50	10	10	10	10				90	450
Adults										
F	25	25	25	25	25	15	20	5	205	1,025
H	25	10	10	10	10				65	325
C	25	25	25	25	25				125	625
V	25	25	25	25	25				125	625
B	25	25	25	25	25	25	15	10	225	1,125
K	25	25	25	25	25	25			125	625
Total: each position	570	290	290	290	290	115* (230)	50* (100)	15* (30)	2,090	
Total: five positions	2,850	1,450	1,450	1,450	1,450	575* (1,150)	250* (500)	75* (150)		10,450

* Number of judgments at each position made with each eye; parenthetical number below is for right and left eyes.

ACUITY OF DISTANCE PERCEPTION

As shown in Table 2, which gives the total number of judgments at each position for each observer, Series 1 was presented to all the observers in this experiment. This series aimed to determine the smallest distance nearer than the standard distance at which each observer could be reliably sure that the variable was nearer than the standard (x-distance); the experimenter varied no other factor than the distance of the stimulus lights from the observer.

In Table 3 the x-distances of children and adults are listed separately, with the corresponding differences in visual angle from that of the standard, with the differences in size of the retinal images, and with the binocular parallactic angles.

The last, a measure of the stereoscopic effect produced by the slightly different positions in space of the two eyes, was of necessity calculated rather indirectly, due to the fact that the separation of the stimuli was greater than the interpupillar distance. The method of calculation varies from that of other experiments (14,1) since they have not taken into account that a difference in interpupillar distance changes the relation of the eyes to the objects; they have therefore made all calculations on the basis of a right angle triangle instead of providing for variations from the right angle with interpupillar distance. The method of determining the binocular parallactic angle follows:

A=center of left object, nearer. To compare its angle graphically with that of B it is juxtaposed to the right andlettered A'.

B=center of right object, farther.

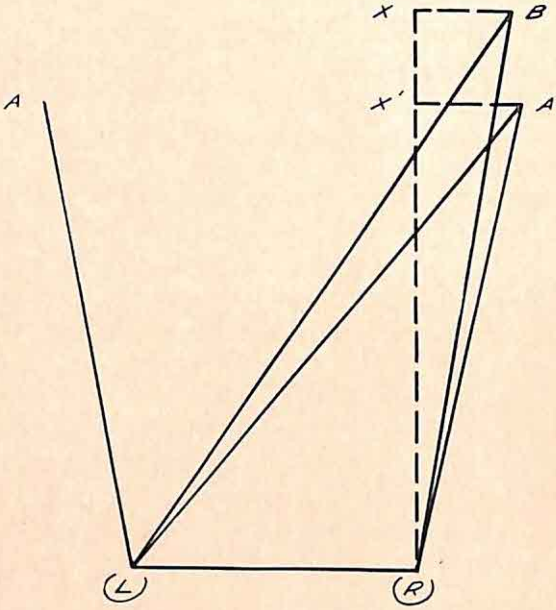
L and R indicate left and right eyes.

LR=interocular distance.

LB=distance from left to right object, measured.

In order to find ∠BLA′ which is the binocular parallactic angle the two angles ∠BLR and ∠A′LR must first be calculated.

Since A and B move along adjacent tracks the distance between them is constant at equal distances from the observer. One-half of this distance less the interocular distance equals XB, the line joining a perpendicular from R to the plane of B. This line RX represents the scaled distance from the observer and is therefore known.



(1) $\frac{BX}{XR} = \tan \angle XRB$

(2) $\angle XRB + 90° = \angle BRL$

(3) $\sin \angle LBR = \frac{LR \times \sin \angle BRL}{LB} = \frac{LR \times \cos \angle LRB}{LR}$

This calculation solves the size of $\angle LBR$. This same calculation is applied to determine $\angle LA'R$ substituting A' and X' for A and X. Then since in $\angle BLR$ (4) $\angle BLR = 180° - \angle LRB - \angle RBL$ and since in $\triangle A'LR$ (5) $\angle A'LR = 180° - \angle LRA' - \angle RA'L$

$\angle BLA'$ (parallactic angle) may be found by subtracting $\angle A'LR$ from $\angle BLR$. These are determined by substituting the known angles in (4) and (5). This subtraction consists practically in solving the equation BLR ($\angle LRA' - \angle LRB$) ($\angle RA'L - \angle RBL$).

The smallest reliably dependable judgments ranged, for children (disregarding F307[4]), from 4 cm. to 12 cm. nearer than the standard at 505 cm. For adults the range was only slightly less, from 2 cm. to 4 cm. nearer than the standard. In other terms, the

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[4] F307 is an anomalous case in that her excess of right judgments over wrong ones at this small distance was so small as to be negligible. This figure represents results on her second set of observations. In the first, in which the range was placed from 3 cm. nearer the standard to 3 cm. back of it, she was entirely successful practically all of the time; thus this series was impracticable from the point of view of comparison with later series; it was therefore supplanted by the above which later is of little positive significance in this discussion.

Table 3

X Distance from Standard with Corresponding Differences in Angle, Binocular Parallactic Angle, and Size of Retinal Image together with Mean, Standard Deviation, Standard Error of Mean, and Standard Deviation of Correct Judgments for Each Observer in the Main Experiment

Observer	Age			Number of Judgments at One Position	X Distance from Standard	Difference in Visual Angle from Standard of 0°40′49.65″	Binocular Parallactic Angle	Difference in Retinal Image from that of Standard (microns)	Correct Judgments, Per Cent	Mean Number Correct in Five Judgments a Day at X Distance	Standard Deviation	Standard Error of Mean	Standard Error of Standard Deviation
	Years	Months	Days										
Children													
F307*	4	4	25	50	2 cm.	20.7″	36″	.78531	54*	2.7*	.90*	.28	.20
F367	4	8	0	25	4 cm.	37.3″	1′ 8″	1.57369	88	4.4	.49	.22	.16
M358	4	5	18	25	4 cm.	37.3″	1′ 8″	1.57369	96	4.8	.40	.18	.13
F381	4	10	25	50	4 cm.	37.3″	1′13″	1.57369	80	4.0	.90	.28	.20
F200	4	2	28	50	4 cm.	37.3″	1′ 8″	1.57369	66	3.3	.90	.28	.20
F384	4	2	21	30	6 cm.	57.9″	1′45″	2.47847	90	4.5	.50	.21	.14
M297	4	7	16	50	10 cm.	1′39.3″	2′59″	4.07152	58	2.9	.83	.26	.19
M382	4	4	2	65	10 cm.	1′39.3″	2′59″	4.07152	74	3.7	1.14	.32	.22
F192	4	8	4	50	12 cm.	2′10.0″	3′44″	4.98735	90	4.5	.67	.21	.15
M269	4	6	18	50	12 cm.	2′10.0″	3′46″	4.98735	72	3.6	1.11	.35	.25
Adults													
F				25	2 cm.	20.7″	38″	.78531	88	4.4	.49	.22	.16
H				25	2 cm.	20.7″	37″	.78531	76	3.8	.40	.18	.13
V				25	2 cm.	20.7″	38″	.78531	72	3.6	1.02	.46	.32
B				25	2 cm.	20.7″	36″	.78531	80	4.0	.63	.28	.20
C				25	3 cm.	28.9″	53″	1.23544	92	4.6	.49	.22	.16
K				25	4 cm.	37.3″	1′12″	1.57369	76	3.8	.75	.34	.24

* Anomalous Case. See footnote page 50.

children perceived a difference in visual angle of 41.3″ and greater, a parallactic angle of 1′8″, and a difference in retinal image of 1.574 square microns or 0.001574 square mm. Helmholtz (10) gives the diameter of one cone as .0045—.0054 mm. by the measurements of Kölliker. This increase, then, is less than the size of one cone but it is impossible to know how many cones are affected by the change. Cones are irregularly placed and this image varies in width as well as in height.

The threshholds (see Table 4) although they are of comparable magnitude, are slightly larger than those determined by Howard (14) and Anderson and Weymouth (1) whose methods are the most similar to this. There are several differing factors which may be explanatory. Both of the above experiments were carried on under much greater illumination, which was not, however, accurately stated. Anderson and Weymouth used natural illumination through a skylight while Howard states only that he used a 75 watt stationary lamp. In Howard's experiment, particularly, the objects had depth as well as surface. Howard's observers, aviators,

Table 4
Parallactic Angles at Positions 1, 2, 4, and 5 for Each Observer in the Main Experiment

Observer	Positions			
	1	2	4	5
		Children		
F307	36″	18″	14″	32″
F367	1′ 8″	36″	32″	1′ 8″
M358	1′ 8″	36″	32″	1′ 8″
F381	1′13″	38″	31″	1′ 7″
F200	1′ 8″	36″	32″	1′ 8″
F384	1′45″	54″	48″	1′35″
M297	2′58″	1′27″	1′23″	2′44″
M382	2′59″	1′26″	1′22″	2′44″
F192	3′44″	1′48″	1′38″	3′18″
M269	3′46″	1′48″	1′37″	3′18″
		Adults		
F	38″	17″	16″	35″
H	37″	19″	14″	35″
V	38″	17″	16″	35″
B	36″	18″	16″	35″
C	53″	29″	25″	35″
K	1′12″	37″	33″	1′ 8″

were known to have particularly high visual acuity. Anderson and Weymouth's observers in the part of the experiment resulting in the smallest thresholds were only three in number; that their vision was "normal" is the only indication of visual acuity. Moreover, the thresholds of these two investigators were determined on two different bases. Anderson and Weymouth determined statistically the 50 per cent successful point and called that the threshold; Howard placed an observer's threshold at the point at which he was correct about 80 per cent of the time. Finally, the comparisons which were to be made in the present experiment were of a different nature than in the other two for the retinal image in this was necessarily of considerable breadth as well as height.

In discussing the perception of small differences in distance by means of the binocular parallax, authorities have varied in point of view. These explanations will be discussed here although it cannot be determined until later whether or not the factor was influential in this experiment.

Helmholtz (10) evidently felt that the binocular parallax was independent of ocular movement; since the thresholds determined by him were not sufficiently small to make physiological explanations difficult, his problem was not complicated. The theories of Hering (12), Bourdon (4), and Stratton (35) need not be discussed here because of their disagreement with later physiological findings. Brooksbank James, writing in 1908, opposed the theory of Brücke that the perceived differences were due to "convergence innervation." He described an experiment devised to exclude all factors excepting this innervation and found discrimination impossible. He proposed that binocular parallax is due to the fact that the image of the nearer object moves more rapidly on one retina than the image of the far object on the other. In the light of the experiments of Dodge (7), McAllister (22), and Dearborn (5), it does not seem likely that such differences in movement are perceived by the observer.

Anderson and Weymouth (1) have offered the most recent explanation of perception of small difference which they term "retinal mean local sign." On the assumption that stimulation is "all or none" in character, and upon the histological evidence that cones in the retina are irregularly placed, they have proposed the following: On account of constant slight movements of the eye there is constant change in area of retina stimulated; this area, although irregular in outline, due to irregularity of cone-placement, has limits for any given stimulation. An average of the successive stimulus patterns within these limits constitutes the basis for discriminating between sensations. Very slight differences in this retinal mean local sign may be sensed.

The integrating influence which is responsible for such a delicately regulated average is not explained. Until such an agent is determined this explanation cannot be verified.

The difference between the performance of such young children and adults is surprisingly small, particularly when it is remembered that four of the children were as successful in making discriminations as was one of the adults. Five out of six adults were more keen in perceiving distance differences than were any of the children, but the degree of superiority was slight. An examination of this same table will also bring out the fact that the variability of the children's judgments was in some cases less than that of the adults (although in some cases more judgments were necessary), and did not run significantly higher. This leads one to conclude that in an experiment of this kind children are practically as consistent observers as adults.

As regards variability, a study of the tables reveals that the three highest standard deviations in relation to the means fall in the last four cases; whether this is due to chance and merely signifies that these three children were not so capable of consistent judgment, or whether there is a more important fact underlying, is difficult to know. A low variability in this matter means that an individual judges practically as well on one day as he does on all others. A high variability means just the opposite; one may judge a certain position absolutely correctly on one day and on the following day fail to discriminate; one may vacillate extremely in other ways. If there are enough good scores on several trials a mean of correct judgments may be high, and yet the variability may also be high. This seems to have happened in the above cases with high standard deviations. It seems possible that individuals who have not so keen a discriminative ability to judge differences in distance are not so sure of their judgments and therefore lose in consistency. The possibility is suggested that the failure to discriminate was due to a fault in attentive ability, as was the variability.

Examination of the particular cases in question does not contribute greatly to the solution of the problem. F192, the only child who had a small standard deviation and who nevertheless was one of the poorest in discriminative ability, was a very consistent observer. She was quiet all through the experimental periods, talked but little, and gave all evidences of putting serious thought on her judgments. Evidently she was actually not able to make the fine discriminations in distance that were possible for the others. Her case points definitely to the fact that all variability is not due to poor ability to discriminate. M269, who had as little discriminative power as had she, seemed to give almost as much consideration to the judgments and evinced as much interest; nevertheless he varied much more from day to day. M297 and M382 were both more inattentive; they talked a great deal and were as quickly fatigued as any in the group. On the other hand, neither of them at any time seemed able to make any finer discriminations than he was making. This brings out another possible explanation; perhaps many mistakes, due to poor discriminative ability, have a discouraging effect which in its turn induces lack of attention. In these cases, particularly, the observers were successful on some days and failed on others. This fact substantiates the last explanation.

It is difficult to be sure whether poor discriminative power and high variability went together because both were due to insufficient attention or because one of them induced the other.

There are in children apparently no significant age differences although the size of the group, as well as the limited age range, makes reservations to this statement advisable. The four children with the highest acuity are found throughout the age range while the two with the poorest acuity are not in the same part of the range.

Due to the small number of cases it was impossible to determine sex differences. Three of the boys were among the four children most lacking in keenness of discrimination and all three of these had high standard deviations in relation to the size of the means. Since variability was low they were either poorer observers than the girls or they did not have such good distance discrimination. In all probability, these differences were due to characteristics of the observers other than those due to sex.

It seems significant that the range of discriminative ability was much wider in the case of the children than in the case of the adults. All of the children were reported by the ophthalmologist to have normal vision, and the adults without normal vision wore corrective glasses. Therefore differences could not have been due, it seems, to physiological differences in the acuity of vision. There remain the following possibilities as explanations of the differences: (1) the ability to sense small differences in area of retinal stimulation was less developed in the children than in adults; (2) the ability to sense the small differences in area of stimulation was developed but the children had not learned to attend to them; (3) the children had not learned to consider small differences in area of retinal stimulation as indicative of differences in distance.

Table 5 shows the results of Series 1 in more detail than Table 3. The mean of correct judgments out of five a day for each position, the standard deviation and the standard deviation of the mean are given for each observer.[5]

According to the underlying theory of the method of constant stimulus differences, the curve of correct judgments for each individual should follow the curve of probability; beginning at the diagnostic point, where judgments are fairly sure, the curve will gradually fall with a lessening of the distance differences until a point is reached where judgments are as likely to be right as to be wrong, where the observer cannot tell which object is nearer to him. This inability to discriminate will hold as the variable approaches the standard and gradually passes from the equal point to distances behind it rather than nearer it. As the variable becomes farther back of the standard, a second diagnostic point is reached.

Since the statistical treatment common to the method of constant stimulus differences was not feasible in this study, as was pointed out in the preceding chapter, due to the variations from the method of presentation, a study of the curves of correct response was made through an examination of the change in mean correct judgments at the five positions. For the present Position 3 will not be considered; because in this position the two stimuli were at exactly equal distances from the observer,—were side by side,—it was not possible for the observer to make a correct judgment; under the conditions of the experiment he was compelled to say that one of the objects was nearer than the other. (Naturally, the observer was

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[5] Complete record by daily trials accompanied by record of change in visual angles may be found in the bound manuscript of this study obtainable from the University Libraries, State University of Iowa, Iowa City, Iowa.

Table 5

Mean Number of Judgments Correct at All Positions in Series 1 of the Main Experiment

Observer	X Distance	Position														
		1			2			3			4			5		
		Mean	S.D.	S.D.$_M$	Mean	S.D.	S.D.$_M$	Mean	S.D.	S.D.$_M$	Mean	S.D.	S.D.$_M$	Mean	S.D.	S.D.$_M$
F307	2cm.	2.7	.90	.28	2.4	1.28	.40	2.1	1.70	.54	2.6	1.02	.32	2.3	1.34	.42
F367	4cm.	4.4	.49	.22	3.2	.98	.44	1.2	.75	.34	3.0	1.10	.49	2.6	.80	.36
M358	4cm.	4.8	.40	.18	3.4	1.02	.46	1.8	1.47	.66	3.0	1.26	.57	3.6	.80	.36
F381	4cm.	4.0	.90	.28	2.9	.70	.22	2.2	.98	.31	3.1	1.14	.36	3.5	1.02	.36
F200	4cm.	3.3	.90	.28	2.6	1.02	.32	1.9	.83	.26	2.5	1.20	.38	2.8	.98	.31
F384	6cm.	4.5	.50	.21	3.3	1.25	.51	3.2	1.34	.55	3.2	.69	.28	4.0	1.15	.47
M297	10cm.	2.9	.83	.26	2.8	.87	.28	1.6	1.36	.43	3.4	.80	2.50	2.8	1.17	.37
M382	10cm.	3.7	1.14	.32	1.8	1.06	.29	2.2	.87	.24	2.7	.82	.23	3.1	1.30	.37
F192	12cm.	4.5	.67	.21	3.8	.87	.28	.7	.78	.25	3.8	.75	.24	4.1	.83	.26
M269	12cm.	3.6	1.11	.35	2.9	.83	.26	2.8	1.47	.47	4.1	.70	.22	4.0	1.00	.32
F	2cm.	4.4	.49	.22	3.6	.80	.36	1.8	.75	.34	3.6	.80	.36	3.6	.80	.36
H	2cm.	3.8	.40	.18	2.8	.75	.34	2.0	1.61	.72	2.8	.75	.34	3.4	1.02	.46
C	3cm.	4.6	.49	.22	4.0	.89	.40	2.8	.75	.34	3.2	.40	.18	4.6	.49	.22
V	2cm.	3.6	1.02	.46	3.0	.63	.28	1.0	1.26	.57	2.2	.98	.44	4.4	.49	.22
B	2cm.	3.0	.63	.28	3.4	1.02	.46	1.2	1.40	.18	3.0	1.10	.49	3.4	.49	.22
K	4cm.	3.8	.75	.34	3.4	.49	.22	3.4	1.02	.46	3.0	.63	.28	4.2	.75	.34

not sure that one was nearer him, since he was in ignorance concerning the positions used.) In these tables, for purposes of comparison with later series, the mean below the column of Position 3 represents the mean of times the left stimulus was judged nearer; therefore any tendency to judge more often on one side than on the other is brought out. To check this, the errors are analyzed into right and left errors, according to whether they were made when the nearer stimulus was on the right of the observer or on the left.

Examining the general form of the curves first, we find that all but four of the sixteen observers, F307, F367, M297, and M269, were decidedly more successful at the two outer positions, Position 1 and Position 5, than they were at the two inner positions. That the curves of these four children did not conform to what was to be expected may probably be explained by the fact that the means which skewed the curves were probably not reliable; they all had high standard deviations. In all these four cases it had been impossible to secure further judgments by these observers, owing to the closing of the preschool laboratories.

Previous experiments have found that the receding threshold is farther behind the standard than the approaching threshold is in front of it; this is explained by the fact that both the visual and the parallactic angles are affected by distance of the object from the eye. If this is true we would expect to find that the mean of correct judgments at Position 1 would be larger than the mean of correct judgments at Position 5, since the difference in angles from the angle of the standard is not so great at the farther position. Examining the tables we find that twelve out of the sixteen observers judged as would be expected; they were not quite so accurate at the back as they were at the front. It is particularly interesting to note that all but one of the children were in this group of twelve. There was one more observer, C, who was equally successful at Position 1 and Position 5. The variation of two of the remaining three, M269 and V is explainable; they both had a high standard deviation of mean at Position 1. Observer K is not so easily explained; not only was her standard deviation of the mean of both positions sufficiently low, but she consistently was equally or more accurate at Position 5 than at Position 1 in all series.

If the relation between judgments back of the standard to those in front of the standard is examined in connection with Positions 2 and 4, the tables show that eight of the observers were more successful at Position 2 than at Position 4, that three more were equally successful, and that the remaining five, all children, were not so successful. This may be pointed out as a tendency only, since not more than six of these differences were significant.

EFFECT OF SIZE OF THE RETINAL IMAGE

Series 2a

In this series the observer judged the nearer of pairs of stimuli presented at the five distances of Series 1. There was one point of difference in the two series: one of the paired stimuli was made slightly smaller than the standard size; this stimulus was always the farther of the two presented . Thus the visual angle was varied from Series 1 without varying the parallactic angle. It can be seen from an examination of Table 6 that the differences in visual angles of the two did not in this series go below those differences which in Table 3 were indicated as large enough to be perceived. The parallactic angles remained as in Series 1. In general, in this series, the difference between angles exceeds the diagnostic angles by about 1′. The differences could, therefore, have been perceived, had the attention of the observers been directed to the fact. This, however, did not prove to be the case. None of the adult observers realized that the circles were not identical in size. Upon being informed of the fact, after the experiment had been completed, each observer expressed surprise and complete ignorance of any possible cue which might have helped in any of the judgments in any of the series. Several of the adults remarked at various times during this series that the judgments seemed exceptionally easy. One of the children, F200, made the following comment on her third trial in this series, "Oh, a big light and a little light! I punched the big light, didn't I?" (A correct judgment on Position 4). After an incorrect judgment at Position 5 she asked, "I punched the little light that time, didn't I?"

Table 7 compares, for each of the fourteen observers participating in this part of the experiment, the average number of correct responses of five a day in Series 1 with the average number correct in Series 2a; Positions 1, 2, 4, and 5 are tabulated separately. At Position 1, there are three cases, F200, H, and B, in which the differences were great enough to be significant. There are four more

Table 6
Size of Visual Angle at the Five Positions for Each Observer in the Main Experiment

Range of Positions	Observer	Position 1	2	3	4	5
		Size of Visual Angle				
		Stimulus 12 cm. in Diameter				
503–507	F307, F, H, V, B	1°22′	1°21′47.6″	1°21′39.3″	1°21′31.0″	1°21′18.6″
502–508	C	1°22′ 8.2″	1°21′55.8″	1°21′39.3″	1°21′26.8″	1°21′10.4″
501–509	F367, M358, F381, F200, K	1°22′16.6″	1°22′	1°21′39.3″	1°21′18.6″	1°21′ 2.0″
499–511	F384	1°22′37.2″	1°22′ 8.2″	1°21′39.3″	1°21′10.4″	1°20′41.4″
495–515	M297, M382	1°23′18.6″	1°22′29.0″	1°21′39.3″	1°20′49.6″	1°20′ 4.2″
493–517	F192, M269	1°23′39.4″	1°22′37.2″	1°21′39.3″	1°20′41.4″	1°19′47.6″
		Stimulus 11.8 cm. in Diameter				
503–507	F307, F, H, V, B	1°20′33.1″	1°20′24.8″	1°20′16.5″	1°20′ 8.2″	1°20′
502–508	C	1°20′45.6″	1°20′33.0″	1°20′16.5″	1°20′ 4.1″	1°19′47.6″
501–509	F367, M358, F381, F200, K	1°20′59.9″	1°20′33.1″	1°20′16.5″	1°20′	1°19′39.3″
499–511	F384	1°21′14.4″	1°20′45.5″	1°20′16.5″	1°19′47.6″	1°19′18.6″
495–515	M297, M382					
493–517	F192, M269	1°22′12.4″	1°21′14.5″	1°20′16.5″	1°19′18.6″	1°18′24.8″

differences which may be said probably to be significant. Of the seven, five are plus differences, meaning significant improvement in Series 2a over Series 1, and two are minus differences. However, if the plus differences are totalled, the minus differences and the cases in which there were no differences, twelve plus differences are found, two of no difference, and two minus differences. Because of the large excess of plus differences over minus it would seem that the addition of so many statistically insignificant differences to the significant ones may be of importance. Although all of the adults either increased their correct judgments or, in one case, maintained the same number, two of the children, F200 and M358 did not do so well. In the latter case the difference probably is not significant, but the significance of the former, statistically, is high: there are 99.5 chances out of 100 that the difference is a significant one. The discussion of this observer will be deferred in order that interpretations may be made in the light of further results.

At Position 2 there is a total of twelve increases in correct judgments, one case of no difference, and one decrease. Six of these differences, all positive, are significant, three more probably so. All of the children made increases, the decrease being in the ranks of the adults. Indications seem to point to the fact that size of the retinal image was more effective at this position than in Position 1. This is explainable on the ground of visual angle: at Position 2 the use of the smaller circle results in a greater difference in angle between the two circles than results in the change of size of stimulus at Position 1.

At Position 4 there was only one observer who did not in Series 2a increase his number of correct judgments over the number correct in Series 1. Seven of the differences are statistically significant and five more are in all probability significant. From the point of view of successes, therefore, this position is indicated as easier than Position 2. However, this cannot be explained by a larger difference in visual angle. The increase in visual angle over Series 1, due to use of the smaller stimulus, is equal at the two positions.

At Position 5 there were five significant increases over success in Series 1 and four more which may possibly have been real increases. There were two decreases, neither of which was significant, one a child, the other an adult.

Table 7

Change in Mean Number of Responses Correct of Five a Day, Positions 1, 2, 4, and 5 in Series 1 and Series 2a of the Main Experiment

Ob-server	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means
	Position 1						Position 2					
	Series 1		Series 2a				Series 1		Series 2a			
Children												
F307	2.70	.90	3.70	.47	+ .10	.39	2.40	1.28	3.30	.47	+ .90	.48
F367	4.40	.49	4.60	.49	+ .20	.31	3.20	.98	3.60	.49	+ .40	.49
M358	4.80	.40	4.40	.80	— .40	.40	3.40	1.02	3.60	1.02	+ .20	.65
F381	4.00	.90	4.20	.75	+ .20	.44	2.90	.70	4.00	.63	+1.10	.36
F200	3.30	.90	2.33	.47	— .97	.39	2.60	1.02	2.67	1.25	+ .07	.79
F384	4.50	.50	4.80	.40	+ .30	.28	3.50	1.25	4.40	.80	+1.10	.62
F192	4.50	.67	4.50	.50	0.00	.33	3.80	.87	4.25	.44	+ .45	.56
M269	3.60	1.11	4.00	1.00	+ .40	.78	2.90	.83	3.50	.50	+ .60	.44
Adults												
F	4.40	.49	4.80	.40	+ .40	.28	5.60	.80	3.60	.49	0.00	.42
H	3.80	.40	5.00	0.00	+1.20	.18	2.80	.75	5.00	0.00	+2.20	.34
C	4.60	.49	4.60	.40	0.00	.31	4.00	.89	3.60	1.02	— .40	.61
V	3.60	1.02	3.80	.40	+ .20	.49	3.00	.63	3.20	1.17	+ .20	.59
B	4.00	.63	5.00	0.00	+1.00	.28	3.40	1.02	4.80	.40	+1.40	.49
K	3.80	.75	4.20	.75	+ .40	.48	3.40	.40	4.00	.63	+ .60	.36

	Position 4						Position 5					
	Series 1			Series 2a			Series 1			Series 2a		
Children												
F307	2.60	1.02	3.00	.67	+ .40	.50	2.30	1.34	4.70	.47	+2.40	.50
F367	3.00	1.10	3.60	.49	+ .60	.53	2.60	.80	4.00	.63	+1.40	.46
M358	3.00	1.26	3.60	.80	+ .60	.67	3.60	.80	4.40	.80	+ .80	.51
F381	3.10	1.14	3.80	.75	+ .70	.50	3.50	1.02	4.20	.75	+ .70	.47
F200	2.50	1.20	3.33	1.25	+ .83	.81	2.80	.98	3.33	1.25	+ .53	.78
F384	3.20	.69	4.60	.80	+1.40	.46	4.00	1.15	5.00	0.00	+1.00	.47
F192	3.80	.75	4.50	.87	+ .70	.50	4.10	.83	4.00	1.22	— .10	.66
M269	4.10	.70	3.00	0.00	—1.10	.22	4.00	1.00	5.00	0.00	+1.00	.32
Adults												
F	3.60	.80	4.40	.49	+ .80	.42	3.60	.80	4.20	.98	+ .60	.57
H	2.80	.75	4.50	.50	+1.70	.49	3.40	1.02	4.00	1.00	+ .60	.85
C	3.20	.40	4.60	.49	+1.40	.28	4.60	.49	4.40	.80	— .20	.42
V	2.20	.98	3.00	.63	+ .80	.52	4.40	.49	4.40	.49	0.00	.31
B	3.00	1.10	5.00	0.00	+2.00	.49	3.40	.49	5.00	0.00	+1.60	.22
K	3.00	.63	4.00	.63	+1.00	.40	4.20	.75	4.80	.40	+ .60	.39

To summarize the effect of repeating Series 1 except for a substitution of a slightly smaller stimulus for the farther of the pair, indications are that the increase of visual angle suggested to the observers a greater difference in distance. Position 4 gained more by the variation than did the other positions, and Position 1 least; Positions 2 and 5 were affected about equally. The increase in difference between visual angles at the various positions due to the smaller circle would have led one to believe that the greater increases would have fallen at Positions 2 and 4, and that Position 5 would have been least affected. That the results do not exactly conform to this order may be explained by the fact that the differences in proportional increase in angle are so small, as are the differences in results, that a small deviation is not surprising.

Series 2b

In this series the observer judged the nearer of a pair of stimuli presented at the five distances at which they were placed in Series 1. There was one point of difference in the two series: one of the paired stimuli was made slightly smaller than the standard size; this smaller stimulus was always the nearer of the two presented. The visual angle was varied from Series 1 without varying the parallactic angle. This series was planned as a check on Series 2a, as well as on Series 1.

Table 8 shows that six of the nine cases of decrease in success at Position 1 from Series 1 to Series 2b were statistically significant; there was one increase which was significant (M269) and two more which may have been. There are three significant decreases, one possibly significant, and one significant increase (also M269) at Position 2 from Series 1 to Series 2b. Two significant decreases and one increase, in addition to one decrease which is undoubtedly a real difference were found at Position 4 from Series 1 to Series 2b. Two significant decreases, two decreases, and an equal number of increases which are possibly significant are shown at Position 5 for these two series. One of the latter was observer M269.

Treating group results as a whole and leaving individual results to be taken up later, it is found that about 25 per cent of the changes from Series 1 to Series 2b are significant decreases. When they are considered in relation to the fact that out of a total of fifty-six instances thirty-one were decreases, while only twenty were increases, there seems to be some reason for believing that the general effect of Series 2b was not only to confuse the observer but to induce him erroneously to perceive the larger of the two stimuli nearer. Calculation of angle differences leads one to believe that the least acute observers, F192 and M269, would be confused in Series 2b more because the angle differences were too small for them to perceive, than because the smaller disc was nearer. In the case of this one range of stimuli (a range of 12 cm. on either side of the standard), the distance compensated for the change in size and the resultant change in angle was a very slight excess in visual angle of the nearer stimulus, except for Position 4. However, the amount of difference in the two angles was not large enough to have been perceived by the two children who needed this large range, according to Series 1. The effect on the two observers was quite different. F192's number of correct judgments decreased at each position, possibly significantly so at Positions 4 and 5. Probably the decrease was due to confusion as a result of too small a visual angle. M269 is harder to explain; there were two significant increases and one which may have been significant. Since subsequent series may be of help in understanding his distance perception, this case will be discussed later in an individual analysis.

Results of Series 2a and 2b indicate that with most of the observers discrimination in Series 1 was by no means wholly dependent on parallactic angle.

In the light of the above results it would be of value in further experimentation to vary the size of retinal image in a slightly different manner. On the basis of the thresholds determined in Series 1 calculation could be made of the size of stimulus which would just appreciably change the size of visual angle for each observer and the smaller circle would be varied in accordance with this calculation. In Series 2a and Series 2b, then, the size of the smaller circle would vary according to the acuity of the observer. The parallactic angle at the just perceivable distance difference could also be calculated and then varied in a manner similar to the variation in visual angle in Series 2a. The relative effect of parallactic angle and visual angle could then be studied.

Table 8

Change in Mean Number of Responses Correct of Five a Day, Positions 1, 2, 4, and 5 in Series 1 and Series 2b of the Main Experiment

Ob-server	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means
	Position 1						Position 2					
	Series 1		Series 2b				Series 1		Series 2b			
						Children						
F307	2.70	.90	2.67	.47	+ .07	.39	2.40	1.28	3.00	1.02	+ .60	.71
F367	4.40	.49	3.60	.49	— .80	.26	3.20	.98	2.80	.40	— .40	.48
M358	4.80	.40	3.20	1.33	—1.60	.63	3.40	1.02	2.80	.75	— .60	.57
F381	4.00	.90	2.60	.80	—1.40	.46	2.90	.70	3.00	1.10	+ .10	.54
F200	3.30	.90	4.00	.82	+ .70	.55	2.60	1.02	3.00	.82	+ .40	.57
F384	4.50	.50	3.40	.80	—1.10	.42	3.30	1.25	3.00	.63	— .30	.58
F192	4.50	.67	4.00	.71	— .50	.42	3.80	.87	3.75	.45	— .05	.36
M269	3.60	1.11	5.00	0.00	+1.40	.35	2.90	.83	4.50	.50	+1.60	.44
						Adults						
F	4.40	.49	3.40	.77	—1.00	.41	3.60	.80	2.80	.75	— .80	.50
H	3.80	.40	4.50	.50	+ .70	.39	2.80	.75	3.00	1.00	+ .20	.79
C	4.60	.49	4.80	.40	+ .20	.28	4.00	.89	2.60	.80	—1.40	.54
V	3.60	1.02	3.00	.63	— .60	.54	3.00	.63	2.20	.75	— .80	.44
B	4.00	.63	.80	1.17	—3.20	.59	3.40	1.02	.40	.49	—3.00	.51
K	3.80	.75	2.40	1.20	— .40	.64	3.40	.49	3.40	.49	0.00	.32

	Position 4						Position 5					
	Series 1		Series 2b				Series 1		Series 2b			
Children												
F307	2.60	1.02	2.67	.47	+ .07	.42	2.30	1.34	2.33	.47	+ .03	.50
F367	3.00	1.10	3.00	.63	0.00	.56	2.60	.80	3.00	1.26	+ .40	.67
M358	3.00	1.26	3.00	1.10	0.00	.75	3.60	.80	3.00	1.41	— .60	.73
F381	3.10	1.14	3.80	1.17	+ .70	.63	3.50	1.02	2.60	1.62	— .90	.80
F200	2.50	1.20	3.00	.45	+ .50	.46	2.80	.98	2.67	.48	— .13	.46
F384	3.20	.69	3.00	1.10	— .20	.56	4.00	1.15	3.60	.49	— .40	.52
F192	3.80	.75	3.00	.71	— .80	.43	4.10	.83	3.50	.87	— .60	.51
M269	4.10	.70	4.00	0.00	— .10	.22	4.00	1.00	4.50	.50	+ .50	.47
Adults												
F	3.60	.80	3.20	.75	— .40	.50	3.60	.80	4.20	.75	+ .60	.50
H	2.80	.75	3.50	.50	+ .70	.49	3.40	1.02	3.50	.50	+ .10	.58
C	3.20	.40	4.20	.75	+1.00	.39	4.60	.49	4.60	.49	0.00	.31
V	2.20	.98	2.20	.75	0.00	.56	4.40	.49	3.60	.77	— .80	.42
B	3.00	1.10	.40	.49	—2.60	.54	3.40	.49	1.40	.49	—2.00	.31
K	3.00	.63	2.20	.40	— .80	.40	4.20	.73	2.80	1.33	—1.40	.69

Table 9

Change in Mean Number of Responses Correct of Five a Day, Positions 1, 2, 4, and 5 in Series 1 and Series 3a of the Main Experiment

Observer	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means
	Position 1						Position 2					
	Series 1		Series 3a				Series 1		Series 3a			
Children												
F307	2.70	.90	4.00	.67	+1.30	.48	2.40	1.28	3.67	.48	+1.27	.49
F367	4.40	.49	4.20	.75	— .20	.40	3.20	.98	4.40	.49	+1.20	.49
M358	4.80	.40	4.00	1.10	— .80	.52	3.40	1.02	3.40	.49	0.00	.51
F381	4.00	.90	4.40	.80	+ .40	.46	2.90	.70	2.20	.75	— .70	.40
F200	3.30	.90	2.67	.47	— .63	.39	2.60	1.02	3.67	.94	+1.07	.63
F384	4.50	.50	4.60	.49	+ .10	.30	3.30	1.25	4.60	.49	+1.30	.56
F192	4.50	.67	4.75	.44	+ .25	.30	3.80	.87	3.25	1.30	— .55	.71
M269	3.60	1.11	4.00	0.00	+ .40	.35	2.90	.83	2.50	1.50	— .40	1.09
Adults												
F	4.40	.49	4.00	.89	— .40	.46	3.60	.80	3.60	1.38	0.00	.72
H	3.80	.40	4.50	.50	+ .70	.39	2.80	.75	3.00	1.00	+ .20	.88
C	4.60	.49	4.80	.40	+ .20	.28	4.00	.89	3.80	.98	— .20	.59
V	3.60	1.02	4.40	.80	+ .80	.58	3.00	.63	3.60	1.20	+ .60	.61
B	4.00	.63	5.00	0.00	+1.00	.28	3.40	1.02	4.60	.49	+ .80	.51
K	3.80	.75	3.40	1.02	— .40	.57	3.40	.49	3.00	.63	— .40	.32

	Position 4						Position 5					
	Series 1		Series 3a				Series 1		Series 3a			
						Children						
F307	2.60	1.02	3.33	1.16	+ .73	.74	2.30	1.34	3.30	.47	+1.00	.50
F367	3.00	1.10	3.80	.40	+ .80	.52	2.60	.80	4.40	.80	+1.80	.51
M358	3.00	1.26	2.80	1.83	— .20	1.00	3.60	.80	3.60	.49	0.00	.42
F381	3.10	1.14	3.80	.40	+ .70	.40	3.50	1.02	4.20	.75	+ .70	.47
F200	2.50	1.20	3.67	.40	+1.17	.44	2.80	.98	3.33	.60	+ .53	.47
F384	3.20	.69	4.00	.89	+ .80	.49	4.00	1.15	4.80	.40	+ .80	.50
F192	3.80	.75	3.75	.44	— .05	.33	4.10	.83	4.80	.44	+ .70	.34
M269	4.10	.70	2.00	0.00	—2.10	.22	4.00	1.00	4.00	1.00	0.00	.77
						Adults						
F	3.60	.80	3.40	.49	— .20	.42	3.60	.80	4.40	.80	+ .80	.51
H	2.80	.75	3.00	0.00	+ .20	.34	3.40	1.02	4.50	.50	+1.10	.58
C	3.20	.40	3.80	.75	+ .60	.39	4.60	.49	5.00	0.00	+ .40	.22
V	2.20	.98	3.80	.75	+1.60	.56	4.40	.49	4.20	.75	— .20	.40
B	3.00	1.10	4.20	.40	+1.20	.52	3.40	.49	4.60	.49	+1.20	.31
K	3.00	.63	3.40	1.36	+ .40	.67	4.20	.75	3.40	.49	— .80	.40

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Table 10

Change in Mean Number of Responses Correct of Five a Day, Positions 1, 2, 4, and 5 in Series 1 and Series 3b of the Main Experiment

Ob-server	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means	Mean Number Correct	Standard Deviation	Mean Number Correct	Standard Deviation	Actual Difference in Means	Standard Deviation of Difference in Means
	Position 1						Position 2					
	Series 1		Series 3b				Series 1		Series 3b			
						Children						
F307	2.70	.90	3.33	.47	+ .63	.39	2.40	1.28	4.33	.47	+1.93	.48
F367	4.40	.49	3.40	.80	—1.00	.42	3.20	.98	3.00	.63	— .20	.52
M358	4.80	.40	4.00	.89	— .80	.28	3.40	1.02	3.00	.63	— .40	.54
F381	4.00	.90	2.40	1.62	—1.60	.78	2.90	.70	2.00	.89	— .90	.46
F200	3.30	.90	2.00	.82	—1.30	.55	2.60	1.02	1.67	.94	— .93	.63
F384	4.50	.50	4.00	1.10	— .50	.53	3.30	1.25	3.80	.40	+ .50	.54
F192	4.50	.67	4.25	.44	— .25	.30	3.80	.87	3.50	1.12	— .30	.63
M269	3.60	1.11	5.00	0.00	+1.40	.35	2.90	.83	4.50	.50	+1.60	.44
						Adults						
F	4.40	.49	4.80	.40	+ .40	.28	3.60	.80	3.80	1.08	+ .20	.60
H	3.80	.40	4.50	.50	+ .70	.39	2.80	.75	3.50	.50	+ .70	.49
C	4.60	.49	4.60	.80	0.00	.42	4.00	.89	4.60	.49	+ .60	.46
V	3.60	1.02	3.60	.49	0.00	.51	3.00	.63	3.20	.40	+ .20	.33
B	4.00	.63	5.00	0.00	+1.00	.28	3.40	1.02	4.40	.49	+1.00	.51
K	3.80	.75	4.40	.80	+ .60	.50	3.40	.49	3.00	.89	— .40	.37

	Position 4						Position 5					
		Series 1		Series 3b				Series 1		Series 3b		
						Children						
F307	2.60	1.02	1.67	.47	— .93	.42	2.30	1.34	2.67	.47	+ .37	.50
F367	3.00	1.10	2.20	.75	— .80	.59	2.60	.80	3.00	.89	+ .40	.54
M358	3.00	1.26	3.00	.63	0.00	.64	3.60	.80	3.40	1.02	— .20	.58
F381	3.10	1.14	3.20	1.33	+ .10	.70	3.50	1.02	3.20	.98	— .30	.45
F200	2.50	1.20	2.33	1.70	— .17	1.45	2.80	.98	2.67	.94	— .13	.62
F384	3.20	.69	2.80	1.16	— .40	.59	4.00	1.15	4.00	.63	0.00	.55
F192	3.80	.75	4.00	.10	+ .20	.25	4.10	.83	5.00	0.00	+ .90	.26
M269	4.10	.70	3.50	.50	— .60	.41	4.00	1.00	3.50	.50	— .50	.47
						Adults						
F	3.60	.80	4.20	1.08	+ .60	.60	3.60	.80	4.20	.40	+ .60	.40
H	2.80	.75	3.00	0.00	+ .20	.34	3.40	1.02	4.00	0.00	+ .60	.46
C	3.20	.40	4.80	.40	+1.60	.25	4.60	.49	4.80	.40	+ .20	.28
V	2.20	.98	2.80	.98	+ .60	.62	4.40	.49	4.00	.89	— .40	.46
B	3.00	1.10	4.40	.80	+1.40	.61	3.40	.49	5.00	0.00	+1.60	.22
K	3.00	.63	3.60	1.20	+ .60	.61	4.20	.75	4.40	.49	+ .20	.40

Table 11

Comparison by Individuals of Mean Number of Correct Judgments of Five a Day, All Positions, in Series 1, Series 2a, Series 2b, Series 3a, and Series 3b of the Main Experiment

Position	Series 1		Series 2a		Series 2b		Series 3a		Series 3b	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Children										
X Distance Equals 505–503 cm. = 2 cm.										
Observer F307										
1	2.70	.90	3.70	.47	2.67	.47	4.00	.67	3.33	.47
2	2.40	1.28	3.30	.47	3.00	1.02	3.67	.48	4.33	.47
3	2.10	1.70	3.00	.67	3.33	.47	1.67	.89	1.33	1.25
4	2.60	1.02	3.00	.67	2.67	.47	3.33	1.16	1.67	.47
5	2.30	1.34	4.70	.47	2.33	.47	3.30	.47	2.67	.47
X Distance Equals 505–501 cm. = 4 cm.										
Observer F367										
1	4.40	.49	4.60	.49	3.60	.49	4.20	.75	3.40	.80
2	3.20	.98	3.60	.49	2.80	.40	4.40	.49	3.00	.63
3	1.20	.75	2.60	1.36	1.00	.89	2.60	1.02	2.40	.80
4	3.00	1.10	3.60	.49	3.00	.63	3.80	.40	2.20	.75
5	2.60	.80	4.00	.63	3.00	1.26	4.40	.80	3.00	.89
X Distance Equals 505–501 cm. = 4 cm.										
Observer M358										
1	4.80	.40	4.40	.80	3.20	1.33	4.00	1.10	4.00	.89
2	3.40	1.02	3.60	1.02	2.80	.75	3.40	.49	3.00	.63
3	1.80	1.47	3.60	.49	2.00	.63	3.00	.63	2.80	1.08
4	3.00	1.26	3.60	.80	3.00	1.10	2.80	1.83	3.00	.63
5	3.60	.80	4.40	.80	3.00	1.41	3.60	.49	3.40	1.02

X Distance Equals 505–501 cm. = 4 cm.										
Observer F381										
1	4.00	.90	4.20	.75	2.60	.80	4.40	.80	2.40	1.62
2	2.90	.70	4.00	.63	3.00	1.10	2.20	.75	2.00	.89
3	2.20	.98	3.20	.94	2.20	1.17	2.80	.75	3.00	.89
4	3.10	1.14	3.80	.75	3.80	1.17	3.80	.40	3.20	1.33
5	3.50	1.02	4.20	.75	2.60	1.62	4.20	.75	3.20	.98
X Distance Equals 505–501 cm. = 4 cm.										
Observer F200										
1	3.30	.90	2.33	.47	4.00	.82	2.67	.47	2.00	.82
2	2.60	10.2	2.67	1.25	3.00	.82	3.67	.94	1.67	.94
3	1.90	.83	2.00	0.00	2.00	0.00	2.33	.47	2.67	1.70
4	2.50	1.20	3.33	1.25	3.00	.45	3.67	.40	2.33	1.70
5	2.80	.98	3.33	1.25	2.67	.48	3.33	.60	2.67	.94
X Distance Equals 505–499 cm. = 6 cm.										
Observer F384										
1	4.50	.50	4.80	.40	3.40	.80	4.60	.49	4.00	1.10
2	3.30	1.25	4.40	.80	3.00	.63	4.60	.49	3.80	.40
3	3.20	1.34	3.00	.40	1.40	1.50	3.00	.40	2.60	1.02
4	3.20	.69	4.60	.80	3.00	1.10	4.00	.89	2.80	1.16
5	4.00	1.15	5.00	0.00	3.60	.49	4.80	.40	4.00	.63
X Distance Equals 505–493 cm. = 12 cm.										
Observer F192										
1	4.50	.67	4.50	.50	4.00	.71	4.75	.44	4.23	.44
2	3.80	.87	4.25	.44	3.75	.45	3.25	1.30	3.50	1.12
3	.70	.78	3.00	.71	2.25	1.48	3.50	.50	3.50	.50
4	3.80	.75	4.50	.87	3.00	.71	3.75	.44	4.00	.10
5	4.10	.83	4.00	1.22	3.50	.87	4.80	.44	5.00	0.00

Table 11 (Continued)

Comparison by Individuals of Mean Number of Correct Judgments of Five a Day, All Positions, in Series 1, Series 2a, Series 2b, Series 3a, and Series 3b of the Main Experiment

Position	Series 1		Series 2a		Series 2b		Series 3a		Series 3b	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Children										
X Distance Equals 505–493 cm. = 12 cm.										
Observer M269										
1	3.60	1.11	4.00	1.00	5.00	0.00	4.00	0.00	5.00	0.00
2	2.90	.83	3.50	.50	4.50	.50	2.50	1.50	4.50	.50
3	2.80	1.47	2.00	0.00	2.00	0.00	1.50	.50	1.50	.50
4	4.10	.70	3.00	0.00	4.00	0.00	2.00	0.00	3.50	.50
5	4.00	1.00	5.00	0.00	4.50	.50	4.00	1.00	3.50	.50
Adults										
X Distance Equals 505–503 cm. = 2 cm.										
Observer F										
1	4.40	.49	4.80	.40	3.40	.77	4.00	.89	4.80	.40
2	3.60	.80	3.60	.49	2.80	.75	3.60	1.38	3.80	1.08
3	1.80	.75	3.20	.40	2.20	.75	2.20	.75	3.40	1.36
4	3.60	.80	4.40	.49	3.20	.75	3.40	.49	4.20	1.08
5	3.60	.80	4.20	.98	4.20	.75	4.40	.80	4.20	.40
X Distance Equals 505–503 cm. = 2 cm.										
Observer H										
1	3.80	.40	5.00	0.00	4.50	.50	4.50	.50	4.50	.50
2	2.80	.75	5.00	0.00	3.00	1.00	3.00	1.00	3.50	.50
3	2.00	1.61	3.00	1.00	1.50	.50	3.00	0.00	3.50	.50
4	2.80	.75	4.50	.50	3.50	.50	3.00	0.00	3.00	0.00
5	3.40	1.02	4.00	1.00	3.50	.50	4.50	.50	4.00	0.00

X Distance Equals 505–503 cm. = 2 cm.										
Observer V										
1	3.60	1.02	3.80	.40	3.00	.63	4.40	.80	3.60	.49
2	3.00	.63	3.20	1.17	2.20	.75	3.60	1.20	3.20	.40
3	1.00	1.26	2.80	.75	2.20	.75	3.40	.49	2.40	.49
4	2.20	.98	3.00	.63	2.20	.75	3.80	.75	2.80	.98
5	4.40	.49	4.40	.49	3.60	.77	4.20	.75	4.00	.89
X Distance Equals 505–503 cm. = 2 cm.										
Observer B										
1	4.00	.63	5.00	0.00	.80	1.17	5.00	0.00	5.00	0.00
2	3.40	1.02	4.80	.40	.40	.49	4.06	.49	4.40	.49
3	1.20	.40	4.80	.40	0.00	0.00	4.00	.63	3.40	.80
4	3.00	1.10	5.00	0.00	.40	.49	4.20	.40	4.40	.80
5	3.40	.49	5.00	0.00	1.40	.49	4.40	.49	5.00	0.00
X Distance Equals 505–502 cm. = 3 cm.										
Observer C										
1	4.60	.49	4.60	.49	4.80	.40	4.80	.40	4.60	.80
2	4.00	.89	3.60	1.02	2.60	.80	3.80	.98	4.60	.49
3	2.80	.75	3.20	.75	2.40	1.20	2.60	1.02	3.20	1.33
4	3.20	.40	4.60	.49	4.20	.75	3.80	.75	4.80	.40
5	4.60	.49	4.60	.80	4.60	.49	5.00	0.00	4.80	.40
X Distance Equals 505–501 cm. = 4 cm.										
Observer K										
1	3.80	.75	4.20	.75	2.40	1.20	3.40	1.02	4.40	.80
2	3.40	.49	4.00	.63	3.40	.49	3.00	.63	3.00	.89
3	3.40	1.02	3.20	.40	1.40	1.02	2.00	1.10	3.60	1.02
4	3.00	.63	4.00	.63	2.20	.40	3.40	1.36	3.60	1.20
5	4.20	.75	4.80	.40	2.80	1.33	3.40	.49	4.40	.49

EFFECT OF LINEAR PERSPECTIVE

Series 3a

In Series 3a the distances used in Series 1 were presented with the following variation: the nearer circle of the pair was always slightly higher than the center and toward the outer edge of the tracks. It was desired to suggest the same effect of linear perspective as was perceived when one of the two boxes was nearer the observer, i.e., the effect of drawing apart.

All positions seemed to be about equally affected by this change, as is shown in Table 9. Out of the fifty-six instances there are thirty-six increases in mean correct judgments in Series 3a over Series 1; twenty-two of these are probably significant. Two of the cases of decreases were significant, M269 and K. There seemed no important difference between results of children and adults.

That a divergent stimulus was suggestive of nearness is probably indicated by the above.

Series 3b

In Series 3b the distances used in Series 1 were presented with the following variation: the nearer circle of the pair was always slightly lower than the center and in toward the middle of the tracks. It was desired to suggest distance. This was a check on Series 3a and designed to determine whether the effect would be confusing to the observer.

Table 10 indicates that although there were thirty cases of increase in mean correct judgments of Series 3b over Series 1, there were twenty-two cases of decrease; of the former, twelve were significant, of the latter, five were significant. Four out of five of the significant decreases occurred with M358, F381, and F200. Since those three cases will be discussed more fully later as individuals, it is sufficient to point out here that all of these changes in means of correct judgments were negative changes, indicating a definite tendency on the part of these individuals.

All of the decreases, except for two that were insignificant, occurred among children; all of the changes in the adults' judgments were increases. Considering these changes as indicative of a general tendency, one is faced with the necessity of explaining this seeming difference between children and adults. Is it not feasible to suppose that any change in linear perspective suggested nearness to the adults while to the children the effect was confusing? It is barely possible that a child who is still building up some of his perceptions attends more to the direction of the perspective than does the adult; in that case he realizes that the circle out of line is distant rather than near. If his analysis is not so complete it may still be sufficient to be confusing.

The results of the Series 2a, 2b, 3a, and 3b, indicate that judgments in Series 1 were in part, at least, based upon empirical factors.

INDIVIDUAL DIFFERENCES

Table 11 compares performance in the first five series by individual children and adults.

From the examination of Tables 7, 8, 9, 10, and 11 it is obvious that all individuals did not react alike to the presented stimuli; nor can important differences be determined between the children and the adults, except in the one case of Series 3b. This fact in itself is significant from the point of view of the study as a whole. It remains to be determined whether there are types of individuals or whether these results are merely individual variations.

In the following citations general tendencies to increase or decrease in number of successful judgments, due to variables, have been considered, as well as significant differences.

To three of the children, F367, F384, and F381 a larger retinal image suggested nearness, a smaller one suggested distance; a spreading of the stimuli suggested nearness and drawing together of the stimuli suggested distance. These children were the only observers whose results coincided with what had been expected.

In addition to the three above, six observers, F192, M358, F, B, V, and K concluded that a larger retinal image meant nearness and a smaller, farness. Observer C had no consistent tendency in either Series 2a or 2b, judging the larger circle nearer part of the time, and often judging the smaller circle nearer. Series 2a and 2b affected M269's judgments alike; both the smaller and larger circle suggested nearness. There seemed a slight tendency for the smaller circle to mean nearness to F200.

Therefore, for nine observers, five children and four adults, out of the fourteen who observed in this section of the experiment, size of the retinal image was an influential factor; a large retinal image suggested nearness and a smaller retinal image, farness. One observer, C, was not judging on the basis of size of retinal image, evidently. F200 seemed to have a tendency to reverse the usual: she interpreted a smaller image to mean nearness and a larger one to mean farness.

For four individuals linear perspective was, in both Series 3a and 3b, an assisting factor: F200 judged linear perspective as did F367, F384, and F381, i.e., diverging stimuli meant nearness and a converging one, farness.

Excepting for K and F, a diverging stimulus suggested nearness to the adults; K decreased her successes and F seemed confused. All of the children excepting M358, F192, and M269 interpreted the stimulus up and away from the center to be the nearer. The two latter seemed not to be consistent: in both of the cases divergence seemed to suggest farness, but at the two extreme positions the stimulus which was up and out was judged correctly more often than in Series 1 (except for M269, Position 5).

Ten individuals were sufficiently influenced by the stimulus which was away from the center and above it to judge it nearer. One observer consistently considered it the farther stimulus.

In addition to F267, F384, F381 and F200 no observers could be said reliably to be interpreting a convergent stimulus to mean farness; M358 seemed to judge it so, but to him a diverging stimulus also meant farness.

The two observers who have not been mentioned, F307 and H, had reactions which differed from all the rest. The effect of each of the last four series was to increase the number of correct judgments over those in Series 1. For F307 this may be explained by the fact that her judgments on Series 1 were so variable (see page 50) that almost anything could easily have chanced to be an improvement. It is also true that this child may have realized the difference between the two circles and, when she could perceive the difference, have judged the variable to be the nearer. She said, "That one looked farther away but I knew it wouldn't get a red light so I pushed the other one." This was by no means always true, for comparatively few of her differences were significant ones. It is possible that H was benefiting from practice and that this accounted for the increase in correct judgments. Her series had to be terminated before as many judgments had been made as in the other cases and it was not possible to make additional observations on Series 1 to determine any possible improvement.

FACTORS INFLUENCING JUDGMENTS ON STIMULI AT EQUAL DISTANCES

At Position 3, Series 1, a correct judgment was not possible; since neither stimulus was nearer and the observer was forced to designate the relative nearness of one of them, no judgment was correct. The procedure in comparing the results in all five series, possible at other positions, must necessarily be varied here. Table 12 gives the bases for determining whether there was any tendency for any of the variations in the stimuli to suggest nearness or farness without an actual change of distance.

For purposes of comparison it may be assumed that a mean of more than 2.5 judgments of ''nearer'' on any one stimulus is indicative of a tendency toward considering that stimulus the nearer one; the farther the distance above or below that midpoint, and the smaller the deviation, the more meaningful the indication.

In Series 2a the larger of the two stimuli was judged to be nearer more than half the time by all but two of the observers, F200 and M269. This tendency of F200 is the same as her tendency at the other position. M269, at the other positions, did not vary in the same manner as he did at Position 3.

Only one of the observers, F307, judged the smaller of the two circles nearer at Position 3, Series 2b. This is not in accordance with her results at the other positions.

At Position 3, Series 3a, nine observers judged the diverging stimulus to be nearer more than half the time. Of the remaining five, there were F307 and F200 who made slight increases at the other positions, M269 and F whose judgments in this series were confused, and K to whom divergence seemed not to suggest nearness.

Judgments at Position 3 in Series 3b are not so well agreed: there were three observers whose means were significant judging the center stimulus nearer, and five significant judgments for the converging stimulus.

It is regretted that it was not possible to give these children a test of ocular dominance. The only test suitable for children of this age was not obtainable in time to be used.

Table 12

Designations of Nearer on Position 3 (Two Stimuli at Equal Distance from the Observer) Mean Number of Five a Day in Series 1, Series 2a, Series 2b, Series 3a, and Series 3b of the Main Experiment

Observers	Series 1		Series 2a		Series 2b		Series 3a		Series 3b	
	Judgments on Left		Judgments on Larger		Judgments on Smaller		Judgments on Higher		Judgments on Lower	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
					Children					
F307	2.10	1.70	3.00	.67	3.33	.47	1.67	.89	1.33	1.25
F367	1.20	.75	2.60	1.36	1.00	.89	2.60	1.02	2.40	.80
M358	1.80	1.47	3.60	.49	2.00	.63	3.00	.63	2.80	1.08
F381	2.20	.98	3.20	.94	2.20	1.17	2.80	.75	3.00	.89
F200	1.90	.83	2.00	0.00	2.00	0.00	2.33	.47	2.67	1.70
F384	3.20	1.34	3.00	.40	1.40	1.50	3.00	.40	2.60	1.02
M297	.80	1.17								
M382	2.20	.87								
F192	.70	.78	3.00	.71	2.25	1.48	3.50	.50	3.50	.50
M269	2.80	1.47	2.00	0.00	2.00	0.00	1.50	.50	1.50	.50
					Adults					
F	1.80	.75	3.20	.40	2.20	.75	2.20	.75	3.40	1.36
H	2.00	1.61	3.00	1.00	1.50	.50	3.00	0.00	3.50	.50
C	2.80	.75	3.20	.75	2.40	1.20	2.50	1.02	3.20	1.33
V	1.00	1.26	2.80	.75	2.20	.75	3.40	.49	2.40	.49
B	1.20	.40	4.80	.40	0.00	0.00	4.00	.63	3.40	.80
K	3.40	1.02	3.20	.40	1.40	1.02	2.00	1.10	3.60	1.02

Series 4

In order to be sure that any changes which may have occurred in the judgments of the observers were due to neither practice nor physiological changes in the condition of the eye, ten of the observers were given a check series, repeating the conditions of Series 1. There were no significant changes.

COMPARISON OF MONOCULAR AND BINOCULAR SERIES

Series 5

In comparing the average number of correct judgments of five observers in Series 1 with the average number correct in Series 5 (repetition of Series 1 with each eye separately), it was hoped to discover whether the use of the two eyes was of benefit to the observer in assisting him to judge more accurately in Series 1 through Series 4 than would have been possible had he been using only one eye.

Indications with F367 were equivocal in nature. The tendency seemed to be for neither eye to be quite so good as both, but this was a tendency only, in some cases one of the eyes was better than both. F381 seemed more accurate with the right eye than with both, at Position 1, probably better with either than with both at position 2 and about the same at Position 4 and Position 5. In general M358 did not seem quite so successful with either eye as with both, although the differences were not significant. B was equally successful with both or either while F was poorer with either eye than with both at all positions except Position 5 at which the differences were not significant.

There were no decided indications that these observers were either helped or hindered by binocular vision in Series 1.

Series 6 and 7

These series repeated the conditions of 2a and 2b with each eye separately. They were designed to discover whether the effect of enlarging the retinal image or decreasing its size for the nearer stimulus would be as influential as proved to be the case in Series 2a and 2b.

With F381, increase in size of the retinal image did not have the decided effect which was found in the two binocular series. In Series 6, the larger stimulus was judged as the nearer by F and B to the same extent with either eye as with both eyes in Series 2a. The decrease of correct judgments by F381 can be explained by a decreasing effort to do well: these series came at the end of the experiment, after it had been in progress for her for eight months, and that the attention of this young observer was waning could be noticed.

Observations in Series 7 were made by only two adult observers. Indications were that decreasing the size of the retinal image of the nearer stimulus was as influential, and in the same manner as in Series 2b.

Therefore, binocular parallax may in all probability be disregarded as an important factor in these observers' judgments of the nearer stimulus in Series 1 through Series 5.

SUMMARY

1. Children four years of age were consistent, reliable, and cooperative observers in a long-time experiment. By means of motivation directly connected with the procedure interest was maintained throughout almost daily experimentation for three or more months.

2. The acuity of perception of the relative distance of objects varying around a standard visual angle of 1°21′39.3″ (12 cm. diameter) at 505 cm. was surprisingly alike for young children and adults. Four children accurately discriminated a difference in visual angle of 37.3″, one an angle of 57.9″, two an angle of 1′39.3″ and two an angle of 2′10″. Four adults distinguished a difference of 20.7″, one a difference of 28.9″ and one a difference of 37.3″. The parallactic angles for the same distance ranged from 1′8″ to 3′46″.

3. There was no significant difference between children and adults in variability of successful response from day to day.

4. The range of acuity of distance perception varied more among children than among adults. Since visual acuity was comparable this difference must be caused by some other factor. Three possible explanations were suggested: (1) the ability to sense small differences in retinal stimulation was less developed in the children than in the adults; (2) the children were capable of discrimination, physiologically speaking, but experience had not taught them to attend to the small differences; (3) the younger observers had not been conditioned to consider small differences in area of retinal stimulation as indicative of differences in distance.

5. No age differences or sex differences could be determined among the children.

6. The curves of correct judgments for both children and adults were consistent in falling as differences in distance near the point of objective equality were approached and in rising as differences receded from the point of equality. The distance differences back of the standard were not so accurately perceived as the same distances in front of the standard.

7. Size of the retinal image and linear perspective were varied separately without the knowledge of the observer with the following results:

a. Individuals differed concerning the extent to which their judgments of relative distance were influenced by the varied factors.

b. Three children interpreted the larger of two retinal images to mean the nearer object, the smaller image to mean the farther object, a divergent stimulus to mean nearness, and a converging stimulus to mean farness.

c. Two children and four adults, in addition to the three children above, interpreted the larger of two retinal images as accompanying the nearer stimulus, and the smaller the farther stimulus. A divergent stimulus suggested nearness to but two of the six. It would seem, therefore, that to these four observers size of the retinal image was of more significance in judgments of relative distance than was linear perspective.

d. One observer, a child, considered the smaller retinal image to refer to a near object and the larger retinal image to refer to the more distant object.

e. One observer who seemed not to be influenced in any definite way by difference in size of the retinal image, indicating that her judgments were based on some other factor, interpreted a diverging line of perspective to mean nearness.

f. Ten observers were sufficiently influenced by divergence of stimulus to judge it nearer.

g. Four of the children, but no adults, considered the converging line of stimulus suggestive of farness, or, at least, considered it the opposite of a suggestion of nearness. This is the only instance of difference between children and adults in the interpretation of these empirical factors.

h. Since in the above situations the size of retinal image and linear perspective were varied without variations in parallactic angle and these variations definitely changed the judgments of distance, it is inferred that factors primarily empirical as well as those primarily physiological were influencing the observers.

8. When one of two stimuli which were at equal distance from the observer was varied in size or in perspective angle, the effect upon the observer was similar to the effect of the same variation of stimuli which were at different distances.

9. When acuity of perception of differences in distance from a standard visual angle of 1°21′39.3″ was determined under conditions of both binocular and monocular vision there were no significant differences found between the two. This indicates that the binocular parallactic angle did not determine the acuity of the observers tested.

10. The effect of variation of size of the retinal image was similar in binocular and monocular series.

SECONDARY EXPERIMENTS

In order to develop other methods of approaching the study of visual distance perception in young children two other sets of apparatus were devised and procedures tried out. Although these experiments were, necessarily, only preliminary in nature, the procedures are described here and results given which seem to be indicative of general tendencies. The data are suggestive and, as such, contribute in some degree to the problem in question.

SECONDARY EXPERIMENT A

This experiment, described in detail in Chapter III, was designed to develop a method of studying the keenness and accuracy of the four- to five-year-old child's perception of differences in distance when two objects are placed at a considerable distance from him. The observer indicated the nearer of two black discs near a standard distance of 195 meters from him. The subjects were fifteen children ranging in age from three years, eleven months to five years, one month, with a mean age of four years, six months.

General Reaction to the Experimental Situation

All of the children understood the fact that they were to choose the nearer circle. The next step, raising the hand in front of the nearer circle, gave trouble to four of the fifteen. Two of them understood when the directions were repeated but thought it far easier to point and usually tried the pointing method until the other was required. The third took longer before comprehension, needing several repetitions and demonstrations (after the experimenter was made to understand his choice). He did, however, learn by the fourth or fifth judgment, although he continued to point first. The fourth case did not learn the principle. The child was unwilling to exert herself in any way whatsoever. With encouragement, in spite of her initially professed inability, she succeeded in making her judgments. She continued, however, to point with assurance to "that one." Finally another unequivocal means of expression had to be devised for her. In the light of these experiences with this part of the procedure it would probably be well, in another set of experiments, to precede the actual series by a preliminary series. This preliminary work would give the child practice in raising the hand in front of the nearer of two objects; the objects should be in closer proximity to the child than the ones in the main series, but should not be close enough for the pointing method to make accurate indications.

Most of the judgments were made in from one to three seconds after the directions had been given. Two of the children consistently took longer to judge, about ten seconds; they gazed intently at the discs, then with conviction put up one hand. There was no relation between degree of assurance and number of correct judgments. Those who were the least successful had as much assurance as their more successful companions and the least certain one was right seven times out of eight.

Analysis of the Data

Upon examination of the recorded responses (see Table 13) it is necessary to recall to mind that the cases were far too few; not only were there a limited number of responses from each child, but fifteen children is a small number. It is obviously out of the question to draw any general conclusion as to individuals, save that a child who had seven or eight, possibly six, correct responses was undoubtedly discriminating, while the child who had less than four right was either not able to discriminate or had not adjusted to the situation sufficiently for his responses to be indicative of his ability.

Table 13

Number of Correct and Incorrect Judgments of Relative Distance at 195 m. Arranged in Relations to Distance from Standard, Positions 1, 2, 4, and 5, in Secondary Experiment A

Observer	Age	Position							
		1		2		4		5	
			Right		Left		Left		Right
	Years Months Days	Right	Larger Disc Nearer	Left	Larger Disc Nearer	Left	Larger Disc Nearer	Right	Larger Disc Nearer
M209	4– 0–19	+	+	—	+	+	—	+	+
M210	4– 3–11	+	+	—	—	—	+	+	+
F318	4– 3–28	—	+	—	—	—	—	+	—
F333	4– 5– 5	+	—	—	—	—	+	+	+
M301	4– 5–29	+	+	+	+	—	+	+	+
M330	4– 6– 6	+	—	+	—	—	+	+	—
M262	4– 2–12	+	+	+	+	+	+	+	+
M323	4– 7– 6	+	—	+	—	—	+	+	—
F329	4– 8– 6	+	+	+	+	+	—	+	—
F268	4– 8–21	+	—	—	—	—	+	—	+
M302	4– 9– 6	+	+	—	+	+	+	+	+
M258	4–10–24	+	—	+	+	—	+	—	+
F191	4–11– 9	+	—	+	—	+	+	—	—
M322	5– 1– 7	+	+	—	+	+	+	—	+
M291	5– 2– 2	+	+	—	—	—	+	+	—
Total Correct		14	9	7	7	6	12	11	9

Four, five, or six judgments right out of the eight indicates that the child was attempting to respond and if the successes were so distributed that they fell with the greatest distance differences, these judgments were probably reliable.

There were six children out of the fifteen who had from six to eight correct responses. The mistakes occurred almost without exception when the distance between the stimuli was one of the smaller ones. These children probably could discriminate accurately between differences of six meters both in front and in back of the standard, differences in visual angle of 31.28″ and 24.86″ respectively. These angular differences are slightly smaller than the smallest distinguished in the Main Experiment. The differences in parallactic angle at this distance are much smaller than in the Main Experiment, differences of 1.44″ and 1.04″. If these results represented more experimentation they would lead one to believe that discrimination here was on the basis of visual angle rather than parallactic angle, since the visual angle is so much more comparable with that in the Main Experiment than is the parallactic angle. The reliability of the conclusion cannot be assured, however, until after more extensive and intensive experimentation. In later experimentation it would probably be advisable to increase the range. This might be done by adding two more distances, 9 m. in front and back of the standard, or by making the differences from the standard 9 m. and 4.5 m. nearer, and 9 m. and 4.5 m. farther.

It is interesting to study the results of the group as a whole. fourteen out of the fifteen children were right when a judgment between the standard (x) and a disc six meters nearer than the standard was required (position 1). Eleven were right with the same difference back of the standard (Position 5). When the distance was reduced to three meters in front of and back of the standard (Positions 2 and 4) the correct judgments out of the fifteen were seven and six respectively. Study of the effect of presenting discs of unequal size, the larger one nearer, shows that there is indicated an improvement in one position, three meters back of the standard; this was one of the two or more difficult judgments. A decrease in correct judgments is found when Positions 1 and 5 are compared with the standard, the back disc being smaller. The first of these differences, the increase, may be explained by the fact that a hard judgment was assisted by the change in size sufficiently to make it slip over the threshold. The decrease is more difficult to explain. A study of the relation between correct judgments and their position in the series may throw some light on the problem.

If right and wrong judgments were tabulated according to their ordinal place in the series, rather than according to their respective positions, it can be found, first, that there were forty-five correct responses in the first four judgments required, and twenty-nine in the last four. It cannot be said, however, that this is wholly indicative of the fact that the child's attention for some reason was not so good at the end, nor that his discriminative powers became fatigued. Rather, further analysis must be made. For purposes of distinction, the two extreme distances may be called easy and the two middle ones hard. It is found that in the first four judgments required there were three easy ones, while there was only one easy one in the last four. The help from the change in size of the farther disc was equal in the two halves. Therefore, the first four judgments were considerably easier than the last four. The judgments were paired in two instances, the standard with an equal disc six meters back comes in the first four, while the same position with a smaller disc back occurs in the last four. The former, supposedly harder than the latter, received eleven correct judgments, the latter received nine. The standard compared with a smaller disc three meters back occurred in the first half, while the standard with an equal disc three meters back was in the second half. The former was supposedly easier and received twelve correct responses, the latter receiving six. The first judgment of all was found to have been right fourteen out of fifteen times, but when the same judgment was supposedly made easier by having the back circle smaller, and this judgment occurred forth, the correct responses were only nine out of fifteen. It would seem, then, that there may be a foundation for the statement that the child's last judgments were poor because of other reasons than his incapability to differentiate between the distances.

In returning to the question raised above, whether the decrease in easy judgments, supposedly made easier by the introduction of a small disc, was due to order of presentation, it is found that there are grounds for supposing this to be the case. The two extreme positions, six meters in front of and in back of the standard, the discs being equal in size, were the first and second judgments made, while their modifications by changed disc size were the fourth and seventh in the series respectively. Probably order of presentation may account for a smaller angle difference calling forth more successful performances than a larger angle difference.

An apparent difference was found between the equal and unequal disc judgments when the distance considered was three meters back of the standard, for the correct judgments increased from six to twelve. There was no corresponding change in judgments involving distance of three meters in front of the standard. It is possible that the apparent improvement may be explained by the fact that the twelve correct judgments came on the third judgment in a series of eight, while the six were in the sixth situation.

Methods of presentation should be changed in subsequent experiments, according to the above results. Not only should the number of judgments be greatly increased but the order of presentation should be arranged, in separate trials, in double fatigue order, so that differences due to order would be cancelled.

Revision of this method, then, would consist in preliminary training of the observer in means of indicating the nearer object, in increasing the range of distances from the standard, and in arranging separate trials in double fatigue order.

Summary

Ninety per cent of the children distinguished an angle difference of 31.28″, 6 m. back of the standard of 195 m., and 73 per cent distinguished an angle difference of 24.16″, 6 m. back of the standard. It was difficult, if not impossible, for these children to distinguish differences of three meters at this distance. Since the visual angle in this experiment is so much more comparable with that of the Main Experiment than is the parallactic angle, it is suggested that the visual angle is more influential in both cases. This is merely suggested and cannot be verified without further experimentation.

On the basis of results found by the above method of experimentation, suggestions have been made for advisable changes in the method. Despite these changes which would improve the method it is, in general, applicable to the study of the problem in question.

SECONDARY EXPERIMENT B

This experiment, described in Chapter III, was designed to develop a method of studying the visual distance perception of young children at a short distance. The observer judged whether a falling ball fell in front of or in back of a partition one meter away. Nineteen children ranging in age from two years, ten months to four years, two months, and sixteen adults observed in the experiment.

General Reactions to the Experimental Situation

This experiment was fortunate in that it attracted the immediate interest of the children and in that this attraction was not short-lived. The frequently observed fact that children enjoy enclosures was borne out repeatedly; "Let me play with the house now." "That's a pretty nice house you have here." "Who made it?" "Why doesn't your house have a roof on it?" It is recorded of one child, "His manner showed a great deal of assurance. . . . He was very coöperative but was more interested in the house itself, how it was made, what made the ball fall, and why it fell so fast. . . ." Some children seemed to feel a direct challenge and wished to succeed for the sake of success. "I missed it!" "Oh, I didn't find it that time." "I find it in here." "I didn't miss it, did I?" "This is a good game. I didn't make any mistakes." It would have been possible to make significant studies of personality differences. There was the child who never looked for the ball without first asking, "In here?" and the one who covered her discomfiture at failing to find the ball by immediately and blithely skipping back to the window saying in the most cheerful and conversational tone, "I didn't find it!" The boy who had always suggested that the experimenter use a particular ball was matched by one who always gave orders as to where the ball should fall. It was observed that every child developed a definite method of entering the house; he either went to the middle spot between the doors in every instance, or to the left of each curtain, or to the right of each curtain. These three methods were chosen about an equal number of times by the children.

Analysis of Data

A study of the group as a whole may be justified in an attempt to find general tendencies. Upon first examination of the data it is noticeable that there was only one distance, 5 cm. back of the 1 m. standard, at which the whole group of nineteen children was successful. In the light of the fact that this was the smallest distance at which the eight centimeter ball was dropped (it should be remembered that distances were calculated from the equator of the ball), this is rather hard to understand. The first and most obvious explanation is that this position always was the first and the child remembered that he went to the back first. It seems, however, rather unlikely that the children would remember, particularly those who had intervening absences. Also, several of the children had occasional errors at this distance, others who first failed at this distance later perceived the difference accurately. Because there was no chance for shadows from the partition to fall upon the ball, the only remaining possibility would be that the children more readily distinguished differences immediately behind the partition than they distinguished those farther away.

It would also seem to be true that distances back of the standard were more easily distinguished than distances in front of it. In every case there is an excess of failure in front of the standard at every distance, although the differences are not significant except just at either side of the standard. In other words, the children went to the back curtain oftener than they went to the front. There is a slight chance that order of presentation favored the back distance, if fatigue is a factor, but this chance is small. The following explanation is proposed in addition to the one given later in the discussion of the reactions of the adults: the very fact that the child is looking through a window into the enclosure may suggest distance to him; therefore he tends to judge the ball farther away than it really is, and tends to go oftener to the back room.

Distance in Relation to Standard

	Back 3.5 cm.*	Front 3.5 cm.*	Back 5 cm.	Front 5 cm.	Back 7 cm.	Front 7 cm.	Back 9 cm.	Front 9 cm.
Total Children Successful	10	10	19	12	16	14	15	13

* Small ball used.

There were no significant differences found due to the use of the small ball interchangeably with the large one in Series 2. This is not surprising, since muscular cues were possible. The adults reported later that they did not notice any difference in the size of the balls.

An examination of the group responses to Series 3 shows that the group as a whole was far less successful in this series. Five children were not successful either in front of the partition or back of it, eight failed in one of the two, six children were successful in both.

At first glance it seems from the data that the younger children were less successful than the older. In order to analyze this further the group of nineteen children, which covers an age range of sixteen months, was divided into two halves according to age. Those children two years, ten months to three years, seven months (nine children) were put in one group; those from three years, seven months to four years, two months (ten children) were put in the other group. The per cent of final scores which were failures was calculated for each group for each series. In Series 1, 27.7 per cent of the responses made by children under three years, seven months in age were failures; from this age to four years, two months only 16.6 per cent of the responses were failures. In Series 2, 40.7 per cent of the responses of the younger group were failures as contrasted with only 8.3 per cent failures of the older children. Failures in Series 3 among the younger children also show a large contrast with those of the older children, 72.2 per cent as against 30.0 per cent.

Upon examination in regard to possible types of individuals one is met with negative results. There were four children (M379, M390, M350, M264) all above three and one-half years of age, who perceived accurately all of the distances presented. Three more children approached complete accuracy; one failed only at the smallest distance (3.5 cm.) front and one (M351) failed to perceive the smallest distance both front and back of the standard, as well as 5 cm. in front of the standard with the small ball. One (F385) failed at 5 cm. front, and 7 cm. front with the larger ball but did so well in the later series that probably she could perceive these distances. Three children (M378, F357, F348) failed quite consistently at distances in front of the standard; two (F365, M324) failed in almost all of those distances back of the standard. It is possible that the results of all of these five children were influenced by failure to attend, lack of effort, or lack of comprehension, but this possibility was felt to exist in only one of the five cases. The character of response of the other four children left little doubt of their sincere attempts.

Of the sixteen adults tested, fifteen perceived all distances in the series; one could not distinguish the small ball at 3.5 cm. in front of the standard. The only failures coming occasionally were: (1) one individual with one failure at 3.5 cm. back and at 7 cm. front of the partition, the small ball in both cases; (2) one adult made one failure each at 7 cm. front with the small ball and 5 cm. front with the large; (3) one adult failed once at 5 cm. back with the small ball; (4) one failed at 5 cm. back with the large ball; (5) one failed at 5 cm. front.

Therefore the results of the adults did not show the scattering of failure responses found in the group of children nor were the failures at such wide range. Totally successful observers represented 83.7 per cent of the adult group as contrasted with 21 per cent of the children. Failures that did occur were found at the smallest distances. Of the eight recorded errors six were on positions in front of the standard. Some of the introspectional reports are interesting in this connection. Eleven observers reported that all the distances back of the standard were easier to judge than those in front, while five adults found no difference in difficulty between front and back distance.

It seemed to most of the adult observers that the front distance nearest them (farthest from the partition) was easier to judge than the distance just in front of the partition. Of the sixteen observers only three realized until so informed that balls of two different sizes had been used. However, it needs to be pointed out that the adults did not have the opportunity to pick up the balls as did the children, and could not therefore discover the size difference. On that account they were neither hindered by the confusion due to speculation as to size of ball nor helped in any way.

It can be noted from the results given above that some revision is advisable before more observations are made. Since the size of the ball seemed to make little difference to the children it would be justifiable to use the small ball entirely; in this way smaller distance differences may be presented. The series should be rearranged to avoid the position of five centimeters back of the standard as the first position in every series. The range of stimuli should be increased but the steps of two centimeters made no smaller; this would necessitate more positions in the series. Probably Series 2 could be omitted until after a more accurate determination of the threshold in Series 1. When presented, the distances considered should be the distances from the partition to the part of the ball which is nearest to the observer.

Summary

These children were able to perceive differences in distance of 5 cm. away from the standard at 1 m. while only five of them were successful at 3.5 cm. There were no significant differences noted when a smaller ball was interchanged with the usual ball. Judgments back of the standard were easier to make than those in front of the standard; this is judged from the results of the children and from the results and introspections of the adults. Fifteen of the adults were completely successful in all three series. One adult made one failure at the smallest distance difference. Age differences are therefore indicated.

In general, the method seems adequate for use in the study of this problem.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study aimed to determine the acuity of visual perception of distance in young children four years of age and to study the rôle in this acuity of the two factors, the size of the retinal image and the linear perspective. As the experiment evolved a secondary study developed, that of the young child as a reliable observer in a psychological experiment of the analytic type.

The observers in the experiment were eighty-nine children ranging in age from two and one-half to six and one-half years attending the preschool laboratories of the Iowa Child Welfare Research Station. Twenty-one adults, graduate students, also observed.

The main experiment was preceded by a study of the vocabulary of two-, three-, four-, five-, and six-year-old children in regard to terms designating relative distance. For the preliminary experiment the words "nearer," "farther," and "closer" were used. In a series of experiments each child pointed to the nearer of two cubes placed within a distance of one meter horizontally, and at a later time pointed to the farther cube. Secondarily, the same words were applied to distance up and down. The data are summarized:

1. The words "nearer" and "farther" were in the passive vocabularies of all the children six years of age and in the vocabularies of a large majority of children four years of age.
2. No children three years of age or under were able to understand the use of these two words in the experimental situation. This was not taken to mean that these children had no visual perception of distance.
3. According to the curve of successful response, an understanding of the meaning of these words develops between the ages of three and six. Within this time range individual development varies.
4. The meaning of "farther" was understood before that of "nearer" but at the middle of the fourth year both were understood by most children.
5. That "nearer" and "farther" had a personal reference was assumed by most of the children.

6. The use of "nearer" and "farther" when applied to distances up and down was not so readily understood as when the same words were applied to horizontal distances.

7. The words "nearer" and "farther" may safely be used in an experimental situation for four-year-old children providing each observer's understanding of the words is first tested.

The second and principal experiment was carried on in a dark room with apparatus especially devised and constructed for the purpose. Ten children between the ages of four years, two months and four years, ten months observed almost daily for a period of from three to six months. The nearer of two circular light stimuli, varying around a standard visual angle of 1°21′31.3″ at a distance of 505 cm. was judged. When the threshold for the perception of distance under these conditions had been determined, observations were made in four subsequent series in each of which a single factor was independently varied from the original series. In two of these series the size of the retinal image was varied: in the first the farther object was made slightly smaller, in the second the nearer object was made smaller by an equal amount. In the other two series the linear perspective was varied: in the first series the nearer object was placed up and slightly out from the center, in the second it was slightly below and toward the center.

The results obtained in the above experimentation with children as observers were compared with those similarly obtained from the observations of six adults. The data are summarized:

1. Children four years of age were consistent, reliable, and cooperative observers in a long time experiment. By means of motivation directly connected with the procedure, interest was maintained throughout almost daily experimentation for a period of three or more months.

2. The acuity of perception of the relative distance of objects varying around a standard visual angle of 1°21′39.3″ (12 cm. in diameter), at 505 cm. was surprisingly alike for young children and adults. Four children accurately discriminated a difference in visual angle of 37.3″, one a difference of 57.9″, one a difference of 1′39.3″, and two a difference of 2′10″. Four adults distinguished a difference of 20.7″, one a difference of 28.9″, and one a difference of 37.3″. The parallactic angles for the same distances ranged from 1′8″ to 3′46″. The difference in size of retinal image for many of these thresholds is smaller than the area of one retinal cone; it must

be remembered, however, that the change in area probably affected many cones.

3. There was no significant difference between children and adults in variability of successful response from day to day.

4. The range of acuity of distance perception varied more among children than among adults. Since visual acuity was comparable this difference must have been caused by some other factor. Three possible explanations were suggested: the ability to sense small differences in retinal stimulation was less developed in the children than in the adults; the children were capable of discrimination, physiologically speaking, but experience had not taught them to attend to the small differences; the younger observers had not yet been conditioned to consider small differences in area of retinal stimulation as indicative of differences in distance.

5. No age differences or sex differences could be determined among the children.

6. The curves of correct judgments for both children and adults were consistent in falling as differences in distance near the point of objective equality were approached and in rising as differences receded from the point of equality. The distance differences back of the standard were not so accurately perceived as the same distances in front of the standard.

7. Size of the retinal image and linear perspective were varied with the following results:

   a. Individuals differed concerning the extent to which their judgments of relative distance were influenced by the varied factors.

   b. Three children considered the larger of two retinal images to mean the nearer object, the smaller image to mean the farther object, diverging stimuli to mean nearness, and converging stimuli to mean farness.

   c. Two children and four adults, in addition to the three children above, considered that the larger of two retinal images resulted from the nearer object, and the smaller image resulted from the farther object. Diverging stimuli suggested nearness to but two of six. It would seem, therefore, that to these four observers size of retinal image was of more significance in judgments of relative distance than was linear perspective.

   d. One observer, a child, considered the smaller retinal image to refer to a near object and the larger retinal image to refer to a more distant object.

e. One observer who seemed not to be influenced in any definite way by difference in size of the retinal image, indicating that her judgments were based on some other factor, interpreted a diverging line of perspective to mean nearness.

f. Ten observers were sufficiently influenced by divergence of stimuli to judge nearness.

g. Four of the children, but no adults, considered the converging line of stimulus suggestions of farness, or at least, considered it the opposite of a suggestion of nearness. This is the only instance of difference between children and adults in the interpretation of these empirical factors.

h. Since in the above situations the size of the retinal image and linear perspective were varied without variation in parallactic angle, and these variations definitely changed the judgments of distance, it is inferred that factors primarily empirical, as well as those primarily physiological, were influencing the observers. This conclusion is supported by the fact that individuals varied to a degree to the extent to which they were influenced by the factors changed.

8. When one of two stimuli which were at equal distances from the observer was varied in size or in perspective angle, the effect upon the observer was similar to the effect of the same variation of stimuli which were at different distances.

9. When acuity of perception of differences in distance from a standard visual angle of 1°21′39.3″ at 505 cm. was determined under conditions of both binocular and monocular vision there were no significant differences found beween the two. This indicates that the binocular parallactic angle did not determine the acuity of the observers tested.

10. The effect of variation of size of the retinal image was similar in the binocular and the monocular series.

In order to develop other methods of approaching the study of visual distance perception in young children, two other sets of apparatus were devised and procedures tried out. Although these secondary experiments were necessarily only preliminary in nature, the procedures were described and the results which seemed to be indicative of general tendencies given. The data are suggestive and therefore contribute in some degree to the problem in question.

Secondary Experiment A.—A method for testing distance perception at 195 m. was devised and presented to fifteen children four years of age. The data showed that 90 per cent of the children distinguished an angle difference of 31.28″, 6 m. in front of the standard at 195 m., and 73 per cent distinguished an angle difference of 24.16″, 6 m. back of the standard. It was difficult, if not impossible, for these children to distinguish differences of 3 m. at this distance. Since the visual angle in this experiment was so much more comparable with that of the main experiment than was the parallactic angle, there is here another indication that the parallactic angle was not used greatly in the main experiment; probably the visual angle was of use in the long distance discriminations. This was merely suggested and cannot be verified without further experimentation. On the basis of results found by the above method suggestions were made for advisable changes in the procedure. Despite these changes which would improve the method it proved in general applicable to the study of visual distance perception at long range.

Secondary Experiment B.—Apparatus was planned to study the visual perception of distance of young children from approximately two and one-half to four years of age at a distance of one meter. The three series of experiments presented to the children were also presented to sixteen adults. The data showed that although the children were able to perceive differences in distance of a falling ball 5 cm. away from the standard at 1 m. only five of them were successful at 3.5 cm. There were no significant differences noted when a smaller ball was interchanged with the original ball. Judgments back of the standard were easier to make than those in front of the standard; this was judged from the results of the children and from the results and introspection of the adults. Fifteen of the adults were completely successful in all three series. Age differences were therefore indicated. On the basis of results suggestions were made for advisable changes in method. In general the method seemed adequate for use in the study of the child's visual perception of distance at short range.

This study has indicated that the young child is a reliable observer in an experiment which is both analytical and technical in type. If methods are so planned that the stimuli under observation are clearly understood by the child, future studies similar in nature may be made in other fields. Upon data thus experimentally gathered may be built a science of child psychology that is yet an unrealized foundation for the science of adult psychology.

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REFERENCES

1. Anderson, Emilie E., and Weymouth, Frank W.: Visual perception and the retinal mosaic. I. Retinal mean local sign—An explanation of the fineness of binocular perception of distance. *Amer. J. Physiol.* 1923, 64, 561-594.
2. Blanton, Margaret Gray: The behavior of the human infant during the first thirty days of life. *Psychol. Rev.*, 1917, 24, 456-483.
3. Blumenfeld, Walter: Untersuchungen über die scheinbare Grosse im Schraume. *Zsch. f. Psychol.*, 1913, 65, 241-404.
4. Bourdon, B.: *La perception visuelle de l'espace.* Paris: Schleicher, 1902, Pp. 442.
5. Dearborn, Walter F.: Retinal local signs. *Psychol. Rev.*, 1904, 11, 297-307.
6. Dodge, Raymond: An experimental study of visual fixation. *Psychol. Rev. Monog. Suppl.*, 1906-1907, 8, No. 4 Pp. 95.
7. Dodge, Raymond, and Cline, Thomas Sparks: The angle velocity of eye movements. *Psychol. Rev.*, 1901, 8, 145-157.
8. Feldman, W. M.: *Ante-natal and post-natal child physiology.* New York: Longmans, Green, Pp. 694, (p. 584-603).
9. Gellhorn, E.: Beiträge zur Physiologie des optishen Raumsinns Pflugers. *Arch. f. d. ges. Physiol.*, 1925, 208, 361-378.
10. Greeff, Richard: Untersuchungen über binokulares Sehen mit Anwendung des Heringschen Fallversuchs. *Zsch. f. Psychol.*, 1892, 3, 21-47.
11. Heine, L.: Schärfe und Tiefenwahrnehmung. *Graefe's Arch. f. Ophthal.*, 1900, 51, 146-193.
12. Helmholtz, H.: *The perception of vision.* Physiological Optics, Vol. III, Trans. by James P. C. Southall, Optical Society of America, 1925, Pp. 736.
13. Hering, Ewald: *Kritik einer Abhandlung von Helmholtz über den Horopter.* Beitrage zur Physiologie, V. Leipzig: W. Englemann, 1861-1864, 287-358.
14. Hillebrand, F.: Theorie d. scheinbaren Grösse bei binokularen sehen. *Denksch. d. k. Akad. Wiss. Wien*, 1902, 72, Pp. 53.
15. Howard, Harvey J.: A test for the judgment of distance. *Amer. J. Ophthal.*, 1919, 2, 656-675.
16. Howard, Harvey J.: Judgment of distance with semaphores and a screen at 100 meters. *Arch. Ophthal.*, 1919, 48, 461-474.
17. Howell, W. H.: *A text-book of physiology for medical students and physicians.* 9th ed. Philadelphia: Saunders, 1924. Pp. 1069.
18. James, Brooksbank: Measurement of stereoscopic visual acuity. *Lancet*, 1908, 1, 1763-1766.
19. Jones, Mary Cover: The development of early behavior patterns in young children. *Ped. Sem.*, 1926, 33, 537-585.

20. Köhler, W.: Optische Untersuchen am Schimpansen und am Haushuhe, Abh. der Koniglich Preussichen. *Akad der Wissenschaften Physikalisch-Math Klasse,* 1915, 3, 1-39.

21. Kuroda, A.: Perception of distance in a two-year-old child. *Jap. J. Psychol.,* 1926, 1, 69-80. Abstract 245, Psychol. Abstr., 1927, 1, 63.

22. Major, David R.: *First steps in mental growth: A series of studies in the psychology of infancy.* Chicago: Macmillan, 1906, Pp. 360, (p. 337-344.)

23. McAllister, Cloyd N.: The fixation of points in the visual field. *Psychol. Rev. Monog. Suppl.,* 1905, 7, 17-53.

24. Moore, Kathleen Carter: The mental development of a child. *Psychol. Rev. Monog. Suppl.,* 1895-1897, No. 3, Pp. 150.

25. Murchison, Carl, and Langer, Suzanne: Tiedemann's observations on the development of the mental faculties of children. *Ped. Sem.,* 1927, 34, 205-230.

26. Peterson, Frederick, and Rainey, L. H.: The beginnings of mind in the new-born. *Bull. City of New York Lying-in-Hospital,* 1910, 1-24.

27. Preyer, William: *The mind of the child. Part I, The senses and the will.* New York: Appleton, 1910. Pp. xxv, 353 (p. 1-71).

28. Preyer, William E.: *Mental development in the child.* New York: Appleton, 1901. Pp. 170 (p. 7-10; 30-47).

29. Reber, Wendell: Heterophoria in children. *J. Amer. Med. Assoc.,* 1916, 67, 186-190.

30. Russell, Bertrand: *Education and the good life.* New York: Boni & Liveright, 1926. Pp. 319 (p. 108).

31. Salzmann, Maximilian: *The human eyeball.* Trans. by E. B. L. Brown. Chicago: Univ. Chicago Press, 1912, Pp. 232.

32. Shinn, Millicent Washburn: *The biography of a baby.* New York: Houghton Mifflin, 1900. Pp. 247.

33. Shinn, Millicent Washburn: Notes on the development of a child. *Univ. California Stud. Parts* 1-4. 1899, 1, Pp. 424 (p. 1-5, 306-322).

34. Starling, Ernest H.: *Principles of human physiology.* Philadelphia: Lea & Febiger, 1912. Pp. 1076. (p. 660).

35. Stern, William: *Psychology of early childhood,* 3 ed. Trans. by Anna Barwell. New York: Holt, 1924, Pp. 557 (p. 121).

36. Stratton, George M.: A new determination of the minimum visible and its bearings on localization and binocular depth. *Psychol. Rev.,* 1900, 7, 429-435.

37. Tanner, Amy: *The Child.* Chicago: Rand McNally, 1915, Pp. 534 (p. 135-161).

38. Titchener, Edward Bradford: *A textbook of psychology.* New York: Macmillan, 1921, Pp. 565 (p. 303-338).

39. Wundt, Wilhelm: *Beiträge zur Theorie der Sinneswahrnehmung.* Leipzig & Heidelberg: 1862, Pp. 105-118.

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